MARCH 1910 VOL. 32 No. 3

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS—Continued

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 MARCH 1910 NUMBER 3

THE New York monthly meeting for March will be held in the Engineering Societies Building, Tuesday evening, March 8, the American Institute of Electrical Engineers participating. The paper will be by H. G. Stott, Mem.Am.Soc.M.E., Superintendent of Motive Power, Interborough Rapid Transit Company, New York, and J. S. Piggott, on Tests of a 15,000-kw. Steam-Engine-Turbine Unit.

The paper relates to the installation of low-pressure turbines at the 59th Street station of the Interborough Rapid Transit Company, New York, and presents a discussion of the most important development in steam engineering since the introduction of the steam turbine. The station is equipped with engines of the Manhattan type, which are double engines having 42 in. horizontal high-pressure cylinders and 86 in. vertical low pressure cylinders with a 5000-kw. generator. The generator is capable of carrying a load of 8000 kw. continuously but the best economy of the engine is obtained at about 5000 kw. and a low-pressure turbine was added to operate on the exhaust steam from the engine, with a view to increasing the capacity of the unit and at the same time improving the efficiency. Two turbines have been installed and the third is in process of installation. By the addition of the turbine the engine can be run to the full capacity of the generator to which is added the current from the turbo-generator, making a total output of 15,000 kw. The paper is published in this issue and gives complete details of the results of tests. An extended discussion is expected by prominent engineers connected with central stations.

BOSTON MEETING, MARCH 11

The next monthly meeting in Boston will be held Friday evening, March 11 in the auditorium of the Edison Electric Illuminating Company. The Boston Section of the American Institute of Electrical Engineers will cooperate in the meeting, and it is expected also that the Boston Society of Civil Engineers will join with these organizations. The paper will be by M. W. Alexander, member Am.Soc.M.E., who has been so long identified with the educational work and training of apprentices and employees at the works of the General Electric Company, West Lynn, Mass. The subject of the paper is The Training of Men, A Necessary Part of the Modern Factory System. This paper was published in the January number of the Journal.

MEETING IN BOSTON, FEBRUARY 16, 1910

A meeting of the American Institute of Electrical Engineers, The American Society of Mechanical Engineers coöperating, was held in the auditorium of the City Club of Boston, February 16. At an informal dinner held at the club preceding the meeting, 250 members and guests were present, while about 500 attended the professional session. The meeting was called to order at 8 o'clock by Prof. Dugald C. Jackson, Mem.Am.Soc.M.E., chairman of the Boston section of the American Institute of Electrical Engineers. David B. Rushmore, Mem.Am.Soc.M.E., chairman of the Industrial Power Committee of the Institute was called to the chair and presided during the presentation of the following papers: The Applicability of Electrical Power to Industrial Establishments, by Dugald C. Jackson, Mem. Am.Soc.M E ; Central Stations vs. Isolated Plants for Textile Mills, by Charles T. Main, Mem.Am.Soc.M.E.; The Supply of Electrical Power for Industrial Establishments from Central Stations, by R. S. Hale, Mem.Am.Soc.M.E.; Illumination for Industrial Plants, by G. H. Stickney; The Requirements for an Induction Motor from the User's point of View, by Walter S. Nye. The discussion was principally upon Mr. Main's introductory paper, Central Stations vs. Isolated Plants for Textile Mills. The meeting was successful in every way, and an indication of the wisdom of engineers in all branches getting together to discuss topics of general interest.

YEAR BOOK FOR 1910

The Year Book of the Society for the year 1910 is now being distributed to the membership. It is issued in new form, designed to

embody the advantages both of the Year Book, as previously issued, and of the Pocket List, which has formerly been published in August of each year.

The Year Book originally had two lists of members, one alphabetical, containing particulars regarding the business, the membership in the Society, and the business and home addresses of each member; and a geographical list, containing only the names of the members. The Pocket List was arranged with the geographical list containing the details regarding the members and an alphabetical list giving only the names, without other information.

In its new form, the Year Book contains a complete alphabetical list as before, and in addition, a geographical list with sufficient information regarding the business title and address of each member to make the list useful to one traveling or to those who desire to correspond with members in any particular city or connected with a particular firm.

The book is issued in a size that is convenient either for the desk or to carry in traveling and is bound in substantial cloth-covered board covers.

STUDENT BRANCHES

UNIVERSITY OF KANSAS

At the first annual meeting on December 9, 1909, papers were presented by S. M. Manley, Mem.Am.Soc.M.E., on A Ten Hour Log of a Boiler Plant; John D. Garver, Student, 1909, on The South American Machinery Market; Louis Bendit, Mem.Am.Soc.M.E., on Economical Power Development; P. F. Walker, Mem.Am.Soc. M.E., on Testing Lubricating Oils; and Paul M. Chamberlain, Mem.Am.Soc.M.E., on Increased Efficiency in the Boiler Room. An opportunity was given to visit plants and buildings in connection with the meeting and the business sessions were followed by a dinner to members and guests. Mr. Chamberlain in his paper, now on file in the headquarters of the Society in New York, discussed at length important features entering into the design and operation of boilers and furnaces, present costs of apparatus and of power plants complete, and the cost to operate coal and ash handling machinery. The organization holds weekly meetings at which technical papers and magazine reports are presented by students, as well as by occasional invited speakers.

PENNSYLVANIA STATE COLLEGE

The first regular meeting of the Pennsylvania State College Student Section as held on January 14, with Aeronautics as the topic for discussion. Prof. Arthur J. Wood, Mem.Am.Soc.M.E., exhibited a small model biplane which he had constructed. At the February meeting Power Plant Accessories were considered.

BROOKLYN POLYTECHNIC INSTITUTE

The student branch of the Brooklyn Polytechnic Institute is preparing to publish an annual, to contain papers by speakers, professors and students. At the January meeting Leon B. Lent, Mem. Am.Soc.M.E., delivered an illustrated lecture on Modern Gas Engines.

SPRING MEETING, ATLANTIC CITY

The Spring Meeting of the Society will be held at Atlantic City, May 31 to June 3 inclusive, with headquarters at the Marlborough-Blenheim. There will be the usual professional sessions, announcement of which will be made later, and on Wednesday evening, June 1, honorary membership will be conferred upon Rear-Admiral Geo. Wallace Melville, U. S. Navy, Retired, and Past-President of the Society.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

Special concessions have been secured for members and guests attending the Spring Meeting in Atlantic City, May 31 to June 3, 1910.

The special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below. Read item *g*.

a Buy your ticket at full fare for the going journey, between May 27 and June 2 inclusive. At the same time request a certificate, *not a receipt*. This ticket and certificate should be secured at least half an hour before the departure of the train.

b Certificates are not kept at all stations. Ask your station agent whether he has certificates and through tickets. If not, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point, and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after June 3.

d An agent of the Trunk Line Association will validate certificates, June 1, 2, 3. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to June 8, on the same route over which the purchaser came, at three-fifths the rate.

g Members and guests from New York City should buy the regular round trip tickets at $5 and show the return portion to Mr. Whitaker or the validating agent.

The special rate is granted only for the following.:

The Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

The Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

The New England Passenger Association except via N. Y. O. & W. R. R. and Eastern Steamship Co. The Rutland R. R. participates in fares reading via its road:

Maine, New Hampshire, Vermont, Massachusettes, Rhode Island and Connecticut.

The Western Passenger Association offer revised one-way fares, on the basis of two cents per mile, to Chicago, Peoria and St. Louis; these three places are points in the Central Passenger Association, and from these points purchase round trip tickets, in the manner outlined in the preceding paragraphs:

North Dakota, South Dakota, Nebraska, Kansas, Colorado, east of a north and south line through Denver, Iowa, Minnesota, Wisconsin, Missouri, north of a line through Kansas, Jefferson City and St. Louis; Illinois, north of a line from Chicago through Peoria to Keokuk.

JOINT MEETING WITH THE INSTITUTION OF MECHANICAL ENGINEERS

BIRMINGHAM AND LONDON, ENGLAND, JULY 26-29, 1910

In response to the invitation of The Institution of Mechanical Engineers to the Joint Meeting of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers to be held in Birmingham and London in July, 117 members and ladies have already engaged passage on the official steamship Celtic, while 205 members, with 155 ladies, have signified their intention of going.

The following tentative program has been outlined by a Committee of the Council of The Institution of Mechanical Engineers.

Tuesday, July 26, 1910. Birmingham.

Morning, 10 a.m. Reception in Birmingham. Professional Session.

Afternoon. Visits to Works, and to Stratford, etc.

Evening. Garden Fête.

Wednesday, July 27, 1910. Birmingham.

Morning. Professional Session.

Afternoon. Visits to Works, etc.

Evening. Reception in Council House, by invitation of the Right Hon. the Lord Mayor of Birmingham.

Thursday, July 28, 1910.

Whole-day Excursions; arriving in London in time to reach hotels and attend late Conversazione at the Institution.

Friday, July 29, 1910. London.

Morning. Professional Session at the Institution of Civil Engineers.

Afternoon. Visits and social functions.

Evening. The Institution Dinner. Including Ladies.

Saturday, July 30, 1910, London.

Whole-day excursions, Windsor and Henley (by invitation).

Evening. Reception at the Japanese-British Exhibition. By invitation.

The Committee are of opinion that members of the American Society will prefer to make their own arrangements for the time between the arrival in Liverpool and the opening of the Meeting in Birmingham at 10 o'clock on Tuesday, as Chester and other places of interest are in the immediate vicinity.

With regard to hotels in Liverpool, the Adelphi, Exchange and Great Western are considered the three principal hotels. Southport ($18\frac{1}{2}$ miles away) is now almost a suburb of Liverpool on account of the frequent service of electric trains, and is a pleasant seaside resort. A list of hotels in Birmingham and neighborhood will be published later.

INVITATION FROM INSTITUTION OF CIVIL ENGINEERS

The following letter of invitation has been received from the Institution of Civil Engineers and acknowledged with appreciation by the Council of The American Society of Mechanical Engineers:

THE INSTITUTION OF CIVIL ENGINEERS
GREAT GEORGE ST., WESTMINSTER, S. W.
11 January, 1910.

Calvin W. Rice, Esq., Secretary,
The American Society of Mechanical Engineers,
29 West Thirty-ninth Street, New York

My Dear Sir,

Hearing from the Institution of Mechanical Engineers that a joint meeting between that Institution and The American Society of Mechanical Engineers is to be held here in July next, the Council of this Institution, at a meeting held today, desired me to request you to be so good as to convey to the members of The American Society of Mechanical Engineers a very cordial invitation to them to avail themselves, during the period of the meeting, of the accommodation which the rooms of this Institution can afford.

I am
Yours faithfully,
J. H. T. TUDSBERY,
Secretary.

REPORTS

MEETING OF THE COUNCIL

At a meeting of the Council, held on Tuesday, February 8, 1910, in the rooms of the Society, there were present Messrs. Abbott, Baker, Bancroft, Bond, Carpenter, Gantt, Hartness, Humphreys, Hutton, Meier, Moultrop, Reist, Smith, Stott, Waitt and the Secretary. Regrets were received from the President and from W. F. M. Goss, Vice-President. On motion Dr. Humphreys acted as Chairman.

The minutes of the meeting of January 11 were read and approved. The Secretary reported the death of Charles Batchelor.

The resignations of R. Carter Beverley, J. S. Avery, Jr., and F. C. Slade were accepted, and announcement of the lapsing of the membership of the following was made by the Secretary: E. E. Barnard, F. E. Bradenbaugh, Jas. Breen, J. M. Briggs, E. D. Clarage, J. C. Dodwell, W. F. Donovan, L. H. Gardner, J. N. Gregory, G. O. Hodge, Nathaniel Lombard, C. F. Meissner, E. E. Miller, Jas. Naughton, H. E. Newell, H. W. Pudan, W. B. Reed, F. A. Schroeder, E. O. Spillman, G. W. Steward, F. P. Thorp, A. A. Thresher, and A. J. Weichardt.

The Executive Committee reported that 49 members had reserved passage on the Celtic, the official steamship for the Joint Meeting in England.

Voted: That the Meetings Committee, in providing for the professional sessions, including papers and discussions, for the Joint Meeting, will entirely fulfill its duty.

The report of F. M. Whyte, Honorary Vice-President, to the National Civic Federation, was received and placed in file.

Voted: That the Secretary be directed to reply to the request for coöperation with the editors of the proposed American Year Book that the Society will be pleased to lend assistance by giving information but can take no official part directly or indirectly in the publication.

Voted: That the invitation of the Institution of Civil Engineers be accepted with thanks, whereby the courtesies of the rooms of

the Institution are extended to the members of The American Society of Mechanical Engineers attending the joint meeting with the Institution of Mechanical Engineers in July 1910.

The election of Rear-Admiral George W. Melville to Honorary Membership by unanimous ballot, was announced.

Resolved: That the checks from the Treasurer be made payable to the order of the cashier and his bond be equal to the maximum amount of funds subject to his control.

Mr. Waitt, Chairman of the Finance Committee, presented a further report regarding the proposed amendments to B18 and C18 that had been referred to the Finance Committee for recommendation and report to the Council.

Voted: That the proposed amendments with the report of the Finance Committee be referred to the Committee on Constitution and By-Laws for report to the Council.

Voted: To approve the application for a student branch at the University of Maine, Orono, Me.

Voted: To approve the modifications of the standards, as approved by the Executive Committee and referred to them under the provisions of the By-Laws, January 21, 1910: general ledger, members card ledger, collection of dues, funds of the society, instructions on savings accounts, instructions on finance report, general information for office.

Notice was also given of proposed amendments to standards on instructions for paying bills, instructions on membership, committee work, election of members, classification of accounts, style sheet, cashier's funds, purchasing, etc.

On motion the meeting adjourned to March 8, 1910.

ABSTRACT OF REPORT OF LIBRARIAN

To the Library Committee:

Books and Pamphlets in the Library during the period July 1, 1908, to December 31, 1909, are listed in the accompanying table. During this time 1531 volumes, chiefly periodicals, have been bound at a cost of $1339.92.

BOOKS AND PAMPHLETS IN THE LIBRARY

	Accessions		Total in Library	
	Books	Pamphlets	Books	Pamphlets
A. S. M. E.	562	67	8,607	1406
A. I. M. E.	1176	2638	18,119	4542
A. I. E. E.	1573	1152	13,936	1248
United Engineering Societies	37	23	37	23
Total	3348	3880	40,699	7219

PERIODICALS

On July 1, 1908, there were 690 current periodicals in the joint libraries, 259 being duplicates, and on December 31, 1909, the number of periodicals regularly received, exclusive of duplicates, was 557.

Seventy-four of the duplicate sets were sold during 1909 at a net profit of $150.21. In addition $111.16 was received from the sale of various books and odd periodicals.

Researches and transcriptions have been made during the period to the amount of $31.

CIRCULATION OF BOOKS

Call cards were placed in commision on March 1, 1909 and the following table indicates the character of the books and periodicals consulted. This tabulation, however, represents only about a third of the circulation, as many people go directly to the shelves and do not ask for information.

Architecture	6	Hydraulic Engineering	17
Bibliography	2	Mathematics	16
Biography	6	Marine Engineering	10
Chemical Technology	25	Mechanical Engineering	102
Chemistry	14	Metallurgy	65
Civil Engineering	19	Mining Engineering	52
Description and Travel	6	Miscellaneous	7
Electrical Engineering	75	Periodicals	111
Electricity	33	Physics	21
Engineering	31	Railroad Engineering	16
General Geology	83	Railroad Engineering, Electric	17
		Total	734

The attendance in the Library is shown in the following table:

LIBRARY ATTENDANCE

JANUARY 1908—DECEMBER 1909

1908	Day	Night	1909	Day	Night
January	541	148	January	485	250
February	439	241	February	533	254
March	417	203	March	536	280
April	403	210	April	529	217
May	400	196	May	462	221
June	419	136	June	484	196
July	441	....	July	472	....
August	362	....	August	472	....
September	392	125	September	434	220
October	381	180	October	471	238
November	435	200	November	479	223
December	520	441	December	545	301
Total	5151	2080	Total	5901	2402

Total for 1908: 7231. Total for 1909: 8303.

During 1909 the general reference section of the Engineering libraries has been strengthened by the addition of the following reference books:

Bartholomew's New Atlas of the World's Commerce.
Bouvier's Law Dictionary, 2 vols.
Calisch's Dictionary of the Dutch Language, 2 vols.
Cyclopedia of Building Trades, 6 vols.
Dietrich's Bibliographie der deutschen Zeitschriften Literatur.
Flügel's Universal German-English Dictionary, 3 vols.
Larousse's Dictionnaire Française, 22 vols.
Meyer's Grosses Konversation Lexikon, 20 vols.
Mullhouse's Italian Dictionary, 2 vols.
Rand & NcNally Business Atlas.
Michaelis's Portuguese-English Dictionary, 2 vols.
Webster's New International Dictionary.
Qui Etes-Vous?
New York Business Directory.
Wer Ist's?

This department is also equipped with:

The Annual Library Index, 1908 (popular engineering material arranged in classes).

The Engineering Index, which is arranged separately in binders by the following classes: civil engineering; electrical engineering; industrial economy; marine and naval engineering; mining and metallurgy; mechanical engineering; railway engineering; street and electric railways.

Engineering Digest.

Le Mois Scientifique et Industriel.

Technical Index.
Reader's Guide.
Poole's Index.
Technical Press Index.
Repertorium der technischen Journal Literatur (superseded in 1908 by Technische Auskunst, published by Bibliographical Institute of Berlin.
Stone & Webster's Current Literature.

There is also a card index of the literature in the engineering periodicals received by the Engineering Societies library. Many of these entries duplicate those of the engineering index, but the library data are available several weeks earlier than the monthly printed index.

The two front alcoves have been arranged to be of practical use to the general public. They possess more advantages than are usually permitted in any of the large public libraries.

To the present equipment will be added very soon:

a Indexes of periodicals and transactions of societies.
b All current foreign periodicals.
c Official patent publications of all countries.
d Lists of periodicals in other libraries.
e The undertaking of researches and translations at hourly rates.
f A bulletin board for new books, and coming meetings and congresses.

Respectfully submitted

L. E. Howard,
Librarian

UNITED ENGINEERING SOCIETY

REPORT OF TREASURER

To the Board of Trustees
United Engineering Society

I beg to submit herewith report of the treasurer as of December 31, 1909.

From the balance sheet submitted herewith it appears that our physical property, over and above the value of the building and our equity in the land, consists of building equipment amounting to $16,767.72, and furniture and fixtures, $2,921.20.

During the current year there have been added to the real estate equipment account a toilet room on the twelfth floor, at an expense

of $530, and furniture and fixtures representing an expenditure of $682.86, including telephone booths, stereopticon, tables, chairs, etc.

It will be noted that the principal of the mortgage on the land, held by Andrew Carnegie, Esq., and amounting originally to $540,000, has been reduced by payments from the land and building funds of the Societies to $223,000, correspondingly reducing the burden on the Founder Societies for payment of interest.

The gross operating expenses for the year were $35,845.92 or, excluding expenditures for building equipment, $530, and furniture and fixtures to the amount of $682.86, a net cost of operating the building for the year 1908 of $32,163.57, slightly in excess of 1908.

In accordance with the resolution of the board an appropriation of $5000 was made out of the surplus remaining from the year 1908 and this amount ($5,037.50) was invested in Baltimore & Ohio bonds, as an addition to the contingency and renewal fund, as provided for in the Founders' Agreement, bringing the reserve fund up to $10,268.75. It is recommended that a similar appropriation be made out of the available balance from this year's operations, leaving a surplus to be carried forward of $3,905.95.

Attention is called to the fact that we had on January 24, 1910, unoccupied floor space in the building equivalent in rental value to only 4 per cent of the total space available for assessment and a part of this small remaining space is under option, so that the only space available and unengaged is the room and ante-room occupied by the Trustees as Board Room, and even that is occasionally called upon for board meetings under assessment for outside parties. One of the Founder Societies is prepared to release one or two rooms for applications from Associates, otherwise the building may be deemed fully occupied.

Your attention is directed to the small number of times the auditorium has been occupied during the year, thirty times as against twenty-seven times in 1908, and the relatively small demand for the two assembly rooms on the fifth floor, occupied fifty-six times in 1909 as against sixty-eight times in 1908. During the past year the facilities of the building were enjoyed by fifty-two societies, Founders and Associates, as against thirty-four in the year 1908. The limited use made of the auditorium and of the assembly rooms on the fifth floor, the income therefrom barely covering their quota of the fixed charges, continues to be a problem in the economical administration of the building.

The chief librarian reports a total attendance during the year of

8303 as against 7231 in 1908, the day attendance showing an increase of 750 and the evening attendance of 322.

The assessments paid for the year by the Founder Societies occupying one entire floor were $6000 each, representing a total expenditure by each, including interest on its full principal of mortgage on the land, of $13,000, reduced in each case to the extent the Society may have paid off part of its mortgage share. As the associate societies are assessed approximately $10,000 for equivalent facilities, it will be seen that the Founder Societies are still carrying more than their proportion of the carrying charges for equivalent office space occupancy in the building.

Respectfully submitted,

(*Signed*) J. W. Lieb, Jr.,

Treasurer

UNITED ENGINEERING SOCIETY

Balance Sheet, January 1, 1910

ASSETS			
Real Estate, Land		$540,000.00	
Real Estate, Building		1,050,000.00	
Real Estate Equipment		16,767.72	
Furniture and Fixtures		2,921.20	
N. Y. City Bonds (cost) Reserve		5,231.25	
Balto. & Ohio Bonds (cost) Reserve		5,037.50	
Accounts Receivable		3,357.00	
Library United Engineering Society		29.05	
Library, adjustment account		30.56	
CASH			
Working Balance	$5,099.88		
For Reserve Fund	5,000.00		
Ways and Means Com	1,165.08	11,264.96	
Petty Cash		500.00	
		$1,635,139.24	
LIABILITIES			
Balance of Mortgage (Land) A.I.E.E		$54,000.00	
Balance of Mortgage, (Land) A. S. M. E.		81,000.00	
Balance of Mortgage, (Land) A.I.M.E		88,000.00	$223,000.00
A.I.E.E. Equity in Building			350,000.00
A.S.M.E. Equity in Building			350,000.00
A.I.M.E Equity in Building			350,000.00
A.I.E.E. Equity in Real Estate Equipment			3,346.61
A.S.M.E. Equity in Real Estate Equipment			3,346.62

A.I.M.E. Equity in Real Estate Equipment	3, 346.62
A.I.E.E. payments to date in liquidation of Mortgage on Land	126,000.00
A.S.M.E. payments to date in liquidation of Mortgage on Land	99,000.00
A.I.M.E. Payments to date in liquidation of Mortgage on Land	92,000.00
Depreciation and Reserve Fund	15,000.00
Ways and Means Committee, etc	1,165.08
Accounts Payable	1,150.00
Balance Cash, Accounts Received, Furniture, etc	17,784.31
	$1,635,139.24

Statement of Receipts and Disbursements Year Ending December 31 1909

Cash

RECEIPTS

Balance on hand January 1, 1909	$6,510.63
Account Reduction of Mortgage on Land	64,000.00
Account Interest on Mortgage	10,740.00
Assessment of Founder Societies	18,000.03
Assessment of Associates, Offices, Meetings	27,363.29
Library Acount	5,109.27
Interest on Bonds	225.00
	$131,948.22

DISBURSEMENTS

Account Reduction of Mortgage on Land	$64,000.00
Account Interest on Mortgage	10,740.00
Operating Expense, Cash Expenditures	30,445.39
Real Estate Equipment	530.00
Furniture and Fixtures	682.86
Library Account	5,195.52
Bonds purchased (reserve)	5,037.50
Accounts Payable (from 1908)	1,399.37
A.I.M.E. return of rentals for office	660.00
Insurance	2,469.49
Library adjustment	688.21
Balance on hand, January 1, 1910	10,099.88
	$131,948.22

Operating Income and Expenses Year Ending December 31, 1909

INCOME

Assessment Founders	$18,000.03	
Less A.I.M.E. refund	660.00	$17,340.03
Assessment Associates		16,746.00
Assessment Miscellaneous (Offices and meetings)		5,991.50
Telephone returns		2,620.70
Miscellaneous charges to Societies		1,828.64
Interest		225.00
		$44,751.87

EXPENSES

Operating Expenses, gross	$32,163.57
Real Estate Equipment	530.00
Furniture & Fixtures	682.86
Reserve Fund	5,000.00
Insurance	2,469.49
Balance to surplus	3,905.95
	$44,751.87

NECROLOGY

CHARLES W. BATCHELOR

Charles W. Batchelor was born in London, England, December 21, 1845. Soon afterwards his parents moved to Manchester, where he received a liberal education and where he served his apprenticeship in several of the largest engineering works of that place. At the age of twenty-two years he came to this country to install some machinery for the Clark Thread Company of Newark, N. J., and almost from the first was for over twenty years intimately associated with the inventor Thomas A. Edison, assisting in the development of the electric pen, the telephone transmitter, the phonograph, the electric railroad and the Edison incandescent lamp and lighting system.

In 1881 he went to Europe to represent the Edison interests at the Paris electrical exhibition of that year, and remained in Paris, for three years where he was the first to introduce the system of electric lighting. He made the original installation at the Paris opera house, and started a number of isolated plants in other parts of Europe; at the same time establishing and managing a large factory at Ivry.

Returning to this country in 1884, he assumed the management of the Edison Machine Works, an organization which in course of time developed into the Edison General Electric Company, and the selection of the site of their large works at Schenectady was made by him. Later this company combined with the Thomson Houston Electric Company and became the General Electric Company.

Of late years he had practically retired from business and devoted much time to travel, though he retained the presidency of the Taylor & Co. iron foundry, a concern in which he had been interested since its establishment.

Mr. Batchelor was a member of the Natural History Museum of New York and the New York Botanical Garden. He was a member for a number of years of the American Geographical Society, the American Institute of Electrical Engineers and the American Electrochemical Society. He entered this Society in 1880.

He died at his residence in this city on January first, 1910.

PERCY A. SANGUINETTI

Percy A. Sanguinetti, one of the early members of the Society, was born in Kingston, Jamaica, B. W. I., June 17, 1844, and died at his home in Mt. Vernon, N. Y., on January 30, 1910.

At the age of 16, he entered service as an apprentice in the locomotive shops of his native town. A few years later he received an appointment to the British Navy Yards at Chatham, England, where he worked through the various departments. During this time he passed a successful examination as teacher of mechanical drawing in the evening mechanical schools at South Kensington, London. In 1867, he was appointed by the Admiralty Board to represent the town of Chatham at the Paris Exposition and to report upon its mechanical features.

His experience in the United States dates from the Centennial Exhibition at Philadelphia in 1876, where he served as assistant to the machinery bureau, designing the system of shafting and the cascade in the pump annex and assisting in the experiments with turbines. At the close of the Exhibition he entered the service of the Franklin Sugar Refinery in Philadelphia, where he remained twelve years, conducting during part of this time a course in mechanical engineering at Franklin Institute. In 1893 he acted as mechanical aid at the World's Columbian Exposition in Chicago and for the following three years occupied the chair of mechanical engineering at the Armour Institute of Technology. In 1895 he came to New York to engage in consulting practice and during the past two years has served in the appraisal bureau of the Public Service Commission.

In 1901, Mr. Sanguinetti secured the coöperation of a score of representative manufacturers of this country in the introduction of American machinery into Jamaica, especially in sugar plantation and power development. His latest work was the remodeling of a sugar refinery near New Orleans, which he completed just two months before his death.

THE TESTING OF WATER WHEELS AFTER INSTALLATION

By Prof. C. M. Allen, Worcester, Mass.

Member of the Society

In the last few years there has been a growing demand for brake tests of water wheels after installation, the object being to determine the horsepower and in many cases the efficiency of the wheels, under actual running conditions, as well as to ascertain whether the wheels are up to their guaranteed rating.

2 The Holyoke testing flume is the only place in the United States where commercial tests of water wheels are made. For purposes of comparison under similar conditions, these tests serve their purpose well and their influence has been great in the development of the modern efficient turbine; but however well a wheel may show up under test made as just described, it may or may not give equally good results after installation. That depends entirely upon the kind of wheel, conditions of setting, and requirements of performance.

3 If the wheel is given a good setting and is allowed to run at the proper speed under a head suited to the design, then it will perform its rated work, which can be accurately computed from the original tests made at Holyoke, provided the wheel is not too large for the testing flume. This flume was not designed to test the largest of our modern turbines, nor is it suitable for testing high-head turbines. If the wheel is not given a fair setting and is required to run at too high a speed (which seems to be almost universal practice), it will fall down on both power and efficiency, the drop in each depending upon the departure from the normal conditions.

4 The efficiency of water wheels under actual working conditions has a very direct bearing upon the conservation of natural resources, and every inducement should be offered to keep that efficiency high. The water wheel as it is leads all other prime movers in efficiency.

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Under ideal working conditions of the steam engine, gas engine and steam turbine, the water wheel has at least three times as good an efficiency as the best of these. If, therefore, by increasing the efficiency of the water wheel, even by a small percentage, we are able to get just so much more power from the same amount of water used, this clearly has a direct bearing on the question of conservation.

5 There is one difference between coal and water, considered as sources of power, which is of more importance than is usually given it, namely: that if water is not used for power, and used efficiently, then that power is lost forever. It is a case of use or lose. The coal not mined or used still remains for the years to come, but the water power not used at all, or not used efficiently, is gone. "The mill will never grind again with the water that is past." As a matter of fact, there are many plants today operated by water turbines that are from 10 to 15 per cent lower in efficiency than they might have been, had the proper kind of installation and setting been definitely known and used. It is, therefore, the desirability of determining the proper setting of the turbine, and the best speed of operation under actual running conditions, that has created, in a large measure, the demand for brake testing after installation.

6 The importance of having a water power developed and operated with maximum efficiency needs no argument; yet of the several reasons that may be mentioned, one of the most important, though apparently not always considered, is purely financial. In the case of several typical hydro-electric installations, for instance, the cost of power house, dam, reservoirs generators, transmission lines, etc., is over 90 per cent of the total, leaving less than 10 per cent for the wheels; but upon the performance of the wheels, depends to a large extent the income from the entire installation. Any increase in the efficiency of these wheels means a direct gain in the power output, and this means, or should mean, not only bigger dividends but also a probable saving of coal somewhere.

7 Wheels have been tested in the last few years in several plants where the difference between the guaranteed efficiency which should have been obtained, and the actual efficiency due to poor settings, was enough to make the difference between a good paying investment and one that did not pay at all.

8 When wheels are installed in hydro-electric stations, and apparently do not show the power and efficiency guaranteed, the question naturally arises, why should a brake test be thought necessary? This may be answered in several ways. In the author's opinion, an

electrical test properly conducted should be sufficiently accurate and reliable in determining the output of the wheels. The reason for making a good many brake tests in the past has been to settle disputes between the hydraulic power and the electrical interests, relative to the guaranteed operation of the plant. The majority of water wheel builders in this country are not willing to abide by the results of an electrical test unless the wheels show up to the guaranteed power by such tests. The generator manufacturers are also unwilling to assume that the generators are low in efficiency, or that their testing apparatus is unreliable. The use of the brake for actually determin-

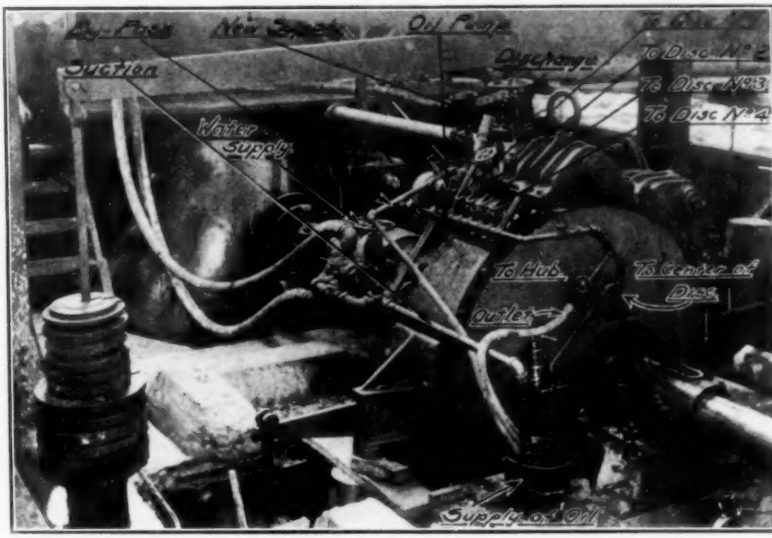

FIG. 1 60-IN. FOUR-DISC DYNAMOMETER; CAPACITY 3000 H.P. AT 200 R.P.M.

ing the horse-power-output of the wheels at the generator coupling is satisfactory to all parties concerned, for the simple reason that the apparatus is very much less complicated and more easily understood. Moreover, the accuracy of the brake can be determined on the ground while under test, as the calibration of the machine can be made at that time, and there is no possible chance for a serious error. In other words, the brake test is the simplest, most accurate, and most direct method of measuring power, and is universally recognized as the standard.

9 In making electrical tests there are many more chances for errors to creep in than in making the brake tests. Ordinarily

several electrical instruments are needed. which should be carefully calibrated before and after tests. These are liable to become changed in transit to the station. Many times they are used under different conditions of temperature, of magnetism, of connection, etc., than when calibrated, and the total results are liable to error on account of the number of instruments to be read, thus bringing in errors which may be more or less cumulative.

10 There is another reason for making brake tests rather than electrical tests at the present time, which is purely a human one. It is that no one but an electrical engineer, or some one with consider-

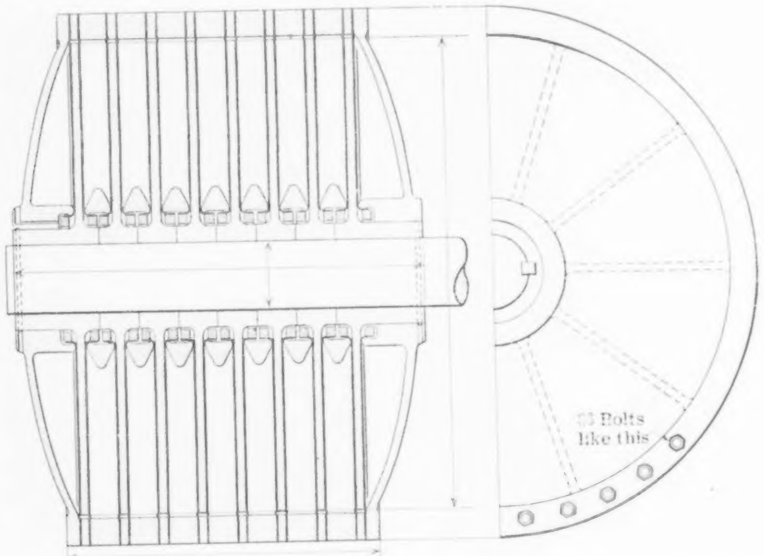

FIG. 2 ASSEMBLY DRAWING OF 28-in. ALDEN ABSORPTION DYNAMOMETER; CAPACITY 2000 H.P., 1800 R.P.M.; EIGHT DISCS

able electrical engineering training, can understand the method used on a complete electrical test, while everyone interested in the plant can understand the method of the mechanical brake test. All parties interested can have their representatives on the ground, to check up all the measurements on the brake and calibrate the dynamometer exactly as it is used under running conditions, and so get with certainty the output of the wheels which is to be delivered to the generator. Furthermore, in order to determine the complete characteristics of the wheels under varying gate openings, and with any considerable variation in speed, it is not always practical to use an electrical generator to furnish the load.

11 It was with the idea of meeting this demand that the Alden absorption dynamometer has been developed and built in large sizes. The principle of the dynamometer is so familiar that only a brief description will be given. It is a form of Prony brake, and usually consists of several smooth circular revolvable cast-iron discs (See Fig. 2), keyed to the shaft which transmits the power; a non-revolvable housing having its bearings upon the hubs of the revolving discs; and a pair of thin copper plates in contact with each cast-iron disc, the plates being integral with the housing. Through a system of piping, water under pressure is circulated through chambers between the units, each consisting of a disc and its copper plates, and between

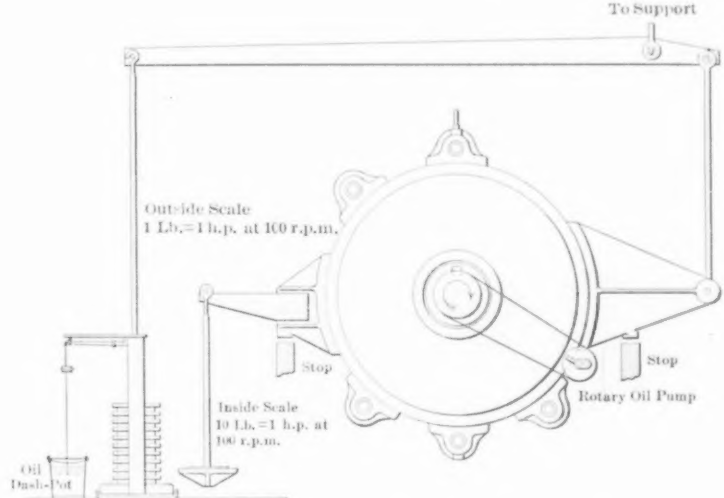

FIG. 3 SKETCH OF DYNAMOMETER SHOWING WORKING PRINCIPLES

the outer plate at either end and the wall of the housing. The water pressure is regulated by hand or by an automatic valve. Another system of piping circulates oil for lubricating the surface of the copper plates next to the revolving discs. In the large-sized machines, oil is impelled by a belt-driven pump mounted on the housing, enters the chambers at the circumference and is forced along the radial grooves of the discs to the hub, and completes its circuit through hose connections to the pump.

12 The power required to drive the pump is measured with, and included in, the power of the dynamometer, for the pump is bolted to the housing, and the driving tension in the belt which operates

the pump tends to rotate the housing in the same manner as does the internal friction of the discs; this makes a calibration to determine power used by the oil pump unnecessary (See Fig. 3).

13 When the dynamometer is in use, water passes through the chambers of the housing and between the several units of plates and discs, and by its pressure tends to force the plates against the sides of the revolving discs. This pressure increases the friction between the discs and plates, and this friction offers resistance to the rotation of the discs. The construction resembles that of a constantly slipping friction disc clutch. The resistance to turning imposed by the friction plates and discs is balanced by the weighing apparatus.

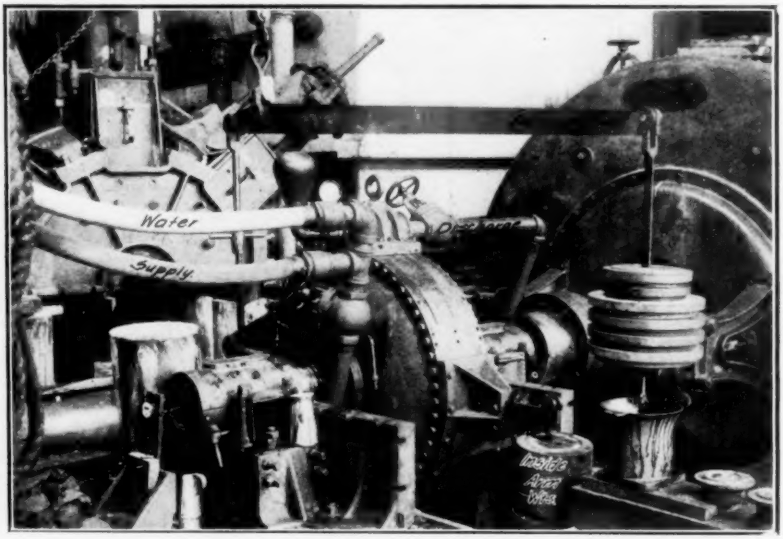

Fig. 4 Method of Counterbalancing Under Load

14 The power transmitted from the wheel under test tends to rotate the housing. This tendency is counteracted by the dead weights or a platform scales, and the housing is kept from rotating, beyond prescribed limits, by stops on either side of a lever arm bolted to the housing. The weighing apparatus by which the power absorbed is measured is delicately adjusted on knife-edge bearings. There are two sets of lever scales, which may be called the outside and inside scales. The outside indicates 1 h.p. for 1 lb. weight per 100 r.p.m. The inside scale indicates 1 h.p. for 10 lb. weight per 100 r.p.m. The outside scale serves not only to assist in balancing

the load—that is, to weigh it—but also to take the weight of the housings from the bearings on the hub of the revolving discs. (See Fig. 3 and Fig. 5.)

15 It is possible to take from the bearings not only the weight of the dynamometer, but also the weight of the shaft. There have recently been made several tests on wheels developing over 2000 h.p., where the entire weight of the dynamometer and shaft (about 13,000 lb. total) was counterbalanced so nicely that the nearest required running bearing was that of the water wheel some seven feet away from the dynamometer. In other words, when the load was on the

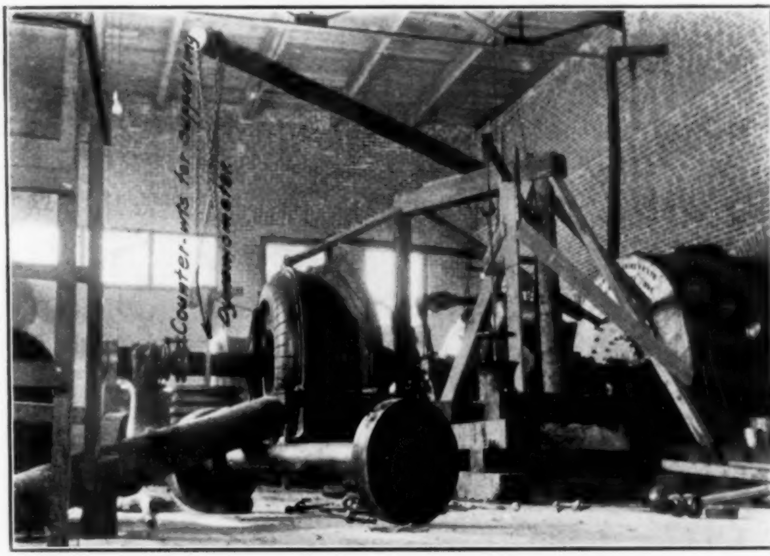

FIG. 5 AUXILIARY METHOD OF COUNTERWEIGHTING UNDER LOAD

dynamometer, it was as if it were placed on an overhanging shaft about seven feet from the nearest bearing. This point is an interesting one in mechanics, and shows that the wheels tested in place can be given a fair treatment under test, in that no additional load due to the weight of the dynamometer is put upon the wheel bearings.

16 To calibrate the dynamometer requires simply the determination of the distance from the center of the shaft to the knife edge bearing of the lever rod, and the ratio of the overhead lever; and the standardization of the dead weight, if used directly, or of the platform scales. Besides this, it is necessary to determine the initial load on

the dynamometer due to the unbalanced effect of the piping, fittings, arms, stops, lever and scale pan. This should be done at the time of test and with the apparatus as used. The usual method employed (shown in Fig. 7) consists in disconnecting the shaft coupling and raising the dynamometer so that parallel irons can be placed under the shaft; by means of a strut under the knife edge on the end of the lever the correct weight of the initial load is then obtained by the use of platform scales.

17 The largest dynamometer built at present consists of four 60-in. discs and has a power-absorbing capacity of 1500 h.p. at 100 r.p.m., or about 3000 h.p. at 200 r.p.m.

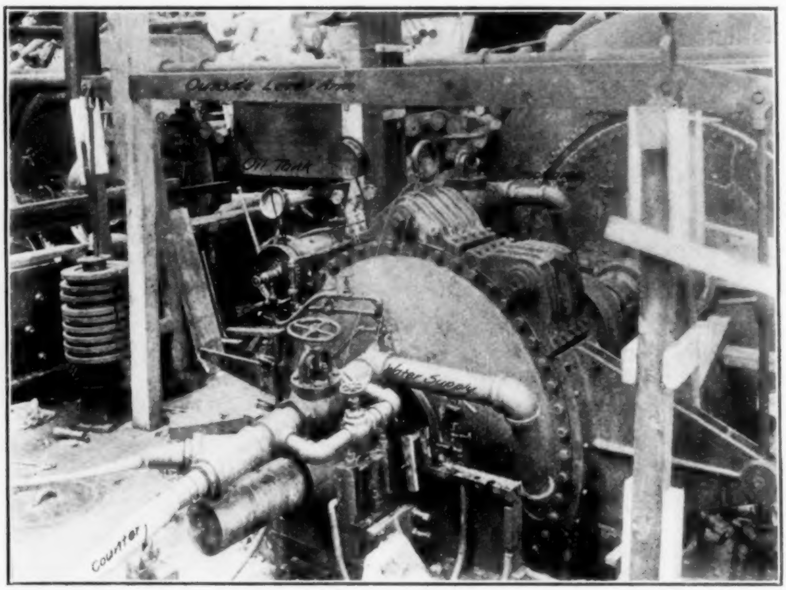

Fig. 6 Dynamometer Rigged for Testing

18 The capacity of the dynamometer is limited by the amount of heat that can be transmitted through the copper plates. This depends upon the range of temperatures and the amount of the circulating cooling water. The capacity is also affected by the kind of lubricating oil used. A cheap grade of cylinder oil has been found satisfactory. A system of forced lubrication is essential to smooth operation.

19 A series of tests has recently been made at the laboratories of the Worcester Polytechnic Institute to determine the relative heat-transmitting properties of copper sheets just as they are received from the rolling mill, and similar sheets electro-copper-plated. These tests were made with a view to increasing the capacity of the dynamometer. The apparatus used consisted of two double-disc Alden dynamometers with the rotating cast-iron discs removed. (See Fig. 8). The dynamometers as tested consisted of an outside cast-iron casing and four copper sheets, with the necessary spacing rings. The dynamometers were identical in every way, except that in one the copper sheets were electro-copper-plated.

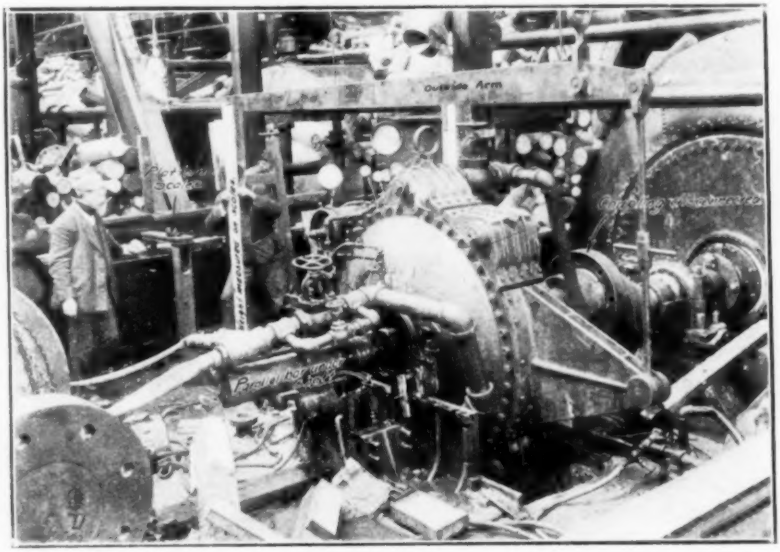

Fig. 7 Method of Calibration After Tests

COUPLING DISCONNECTED, SHAFT RESTING ON PARALLEL BARS, UNBALANCED LOAD OF DYNAMOMETER WEIGHED ON SCALES.

20 The dynamometers were set up so that the spaces normally occupied by the revolving discs were piped to the steam main. Plugs were removed from the top and bottom of these spaces so that all air and condensed steam would be removed. Circulating water was supplied at the bottom of the casings and taken out at the top, both the circulating water and condensed steam being collected and weighed. Thermometers were inserted in the steam line next to the dynamometers and in the water supply line, also in the discharge of

the circulating water and of the condensed steam. Several tests were run on each, of five minutes' duration. The accompanying table gives results of these tests.

	Plain Copper Sheets	Electro-plated Copper Sheets
Average temperature of entering circulating water.	44 deg. fahr.	44 deg. fahr.
Average temperature of exhaust circulating water.	100 deg. fahr.	100 deg. fahr.
B. t. u. per sq. ft. per min. per 50 deg. difference in temperature of circulating water.......	467	610
Increase, in percentage...........................	...	30.8

21 The results were all reduced to a common basis, namely: the B.t.u. transmitted through 1 sq. ft. of copper sheet per min. per 50 deg. difference in temperature of circulating water. The dynamometer containing the copper-plated sheets showed an increased heat transmission of more than 30 per cent over the untreated. A probable explanation of this phenomenon is that when the sheets are electro-copper-plated, the copper is deposited in small globules and the actual surface not only is increased but is made rougher; this tends to mix up the water currents, bringing more new water in contact with the copper.

22 In the actual operation of these dynamometers, the heat is generated on a thin film of oil directly against one side of the copper and the water passes over the surface on the other side, carrying off the heat generated. It is a well known fact that more heat is transmitted through copper than can be readily carried off by the water, and any increase in surface in contact with the water gives a corresponding increase in capacity. As the capacity of these dynamometers depends upon the heat-transmitting power of the copper sheets, it is clear that this capacity can be increased 30 per cent by the use of electro-plated sheets.

23 Owing to the system of continuous forced lubrication, the dynamometers are capable of holding their maximum load for any length of time. A dynamometer recently used held a load of from 2000 to 2300 h.p. during a series of tests on a pair of turbines of over eight hours' continuous running. The reason for making so long a run was that the weir for measuring the water used was situated in the canal above the turbines, and considerable time was required to allow conditions to become constant. It may be of interest to note that this weir was standard, with end contractions, and was

73 ft. long. During the tests, when the wheel gates were wide open, the quantity used by the wheels required a head of 2 ft. on the crest of this weir. Long runs are also required when the current meter is used in measuring the discharge from the wheels.

24 The largest power ever absorbed at one time by these dynamometers was 4100 h.p., developed by a pair of turbines under a head of 110 ft. at a speed of 225 r.p.m. These turbines were used to furnish power for a paper pulp mill. There were six grinders on either side of the turbines, making twelve in all. The grindstones nearest the turbines were removed, and two dynamometers put in their places.

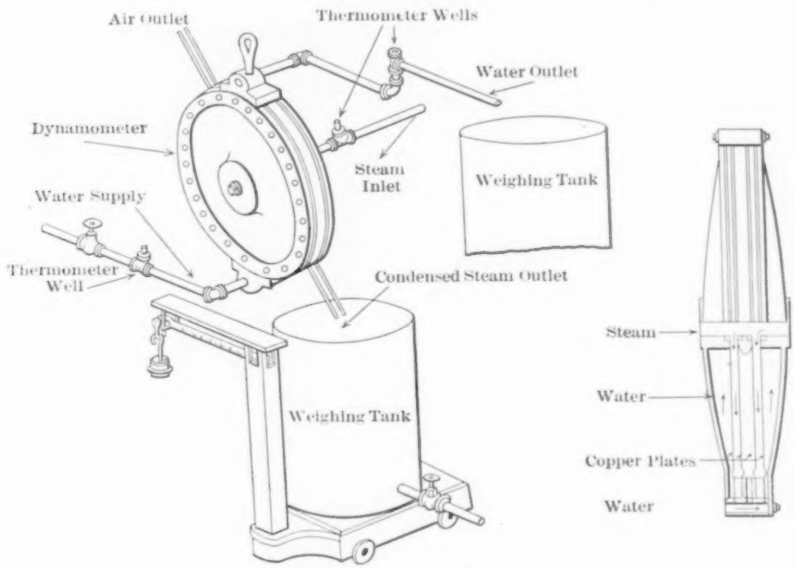

FIG. 8 LAYOUT OF APPARATUS; WITH SECTION OF DYNAMOMETER

25 The amount of work required to make such tests is comparatively small, when the amount of power measured is considered. Two units of approximately 4000 h.p. were tested inside of three days.

26 In pulp mills it is difficult to know how much power the wheels are developing. It is not always safe to base the estimate on quantity of pulp, as there are many variations in the conditions of stones, wood, etc. Hence quite a large percentage of brake testing of wheels has been done in grinder rooms.

27 Several tests of large powers have been made in hydro-electric stations in which case the generators are set aside and the dynamometer mounted on the wheel shaft, usually in place of the half coupling.

28 To give an idea of the actual running conditions sometimes found, a test in one plant showed that the wheels were giving the power called for by the contract, but that if they had been run at 200 instead of 225 r.p.m., the power would have been increased from 2000 to 2300 h.p.; thus showing a waste of 300 h.p. and a correspondingly lessened efficiency. On another test it was found, that when the wheels were running at the guaranteed speed, the power and efficiency were between 30 per cent and 40 per cent lower than they should have been. Removing the entire load only slightly increased the speed.

29 Many tests have been made which show that if the wheels are given a "fair setting," and the speed properly chosen, they will agree closely with the computed ratings made from the tests at the Holyoke flume. One test of a pair of wheels, made after installation, agreed so closely with the computed results from the Holyoke tests of the individual wheels, that the curves showing the relation of the horsepower and efficiency to the speed-gate opening of the pair came between the curves of the separate wheels transferred to the same head basis. The term "fair setting" means that the water should be brought to the wheel with a low velocity; the draft tube should be designed especially for the particular conditions, and should be air-tight; the wheels, if a pair, and center-discharging, should not be set too closely together; if a pair and outward-discharging, end supply should be avoided if a steel penstock is used; the shaft of the wheel should not be larger than necessary; the bearings should be kept in line, etc. The setting just described refers to open flumes or steel penstocks and not to spiral casings.

30 Incidental to the brake testing of water wheels, considerable information has been obtained regarding the efficiency of large bevel gears, such as are commonly used in transmitting power from vertical wheels in low-head installations. About a year ago, a series of tests were made to determine: first, the horsepower delivered to the horizontal generator shaft from two vertical wheels; second, the horse power of the individual vertical wheels. By subtracting the former from the sum of the latter, the loss due to the bevel gears and bearings was obtained. The tests were conducted in the above order so as to get the ouptut at the generator coupling with gears running normally. Then the gears were removed and the individual vertical tests made.

31 The total horsepower delivered to the generator was approximately 700. (See Fig. 9 and Fig. 10). The driving gear was of the

ordinary wood-mortise type, outside diameter 6 ft. 5 in. approximately, with 68 teeth, 14 in. wide, meshing with a cast-iron pinion which had 48 teeth with a planed tooth outline. At full load the loss in the gears was 3.5 per cent and 3.4 per cent for two separate units, or the efficiency of the horizontal-shaft vertical-wheel gear drive was about 96.5 per cent. The gears were well lubricated with a thick grease.

32 About nine months later it was necessary to test one of these same units in exactly the same manner. The loss in gears this time was a trifle less, the tests giving 3.1 per cent. As a matter of fact,

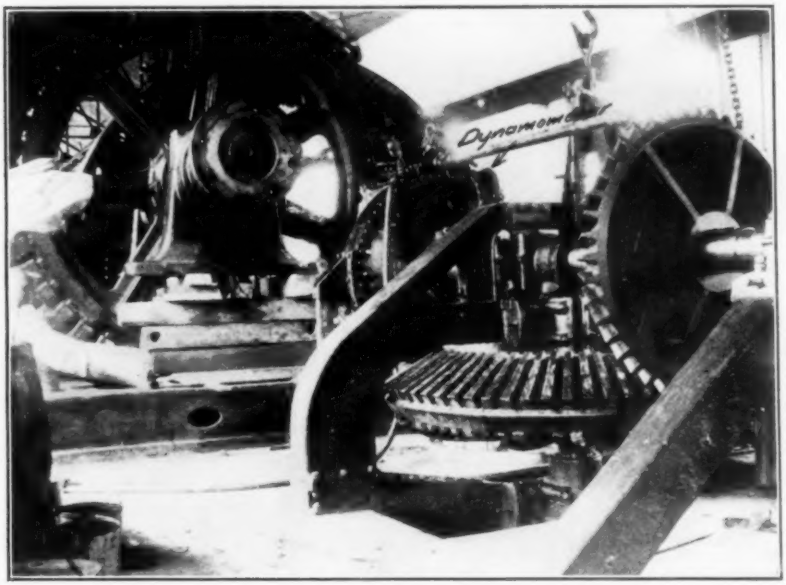

Fig. 9 Horizontal Testing of Vertical Wheels with Bevel Gears

the gears were running smoother at the last test, having had nine months more of service. When the first tests were made, the plant had been running less than a year.

33 Besides this direct measurement of gear efficiencies, two separate tests have been made within the past year, of two vertical Boyden wheels with the power measurements made on the horizontal shaft. These wheels had been in operation for over thirty years. The bevel gears (both the driving and the driven) were of cast iron in each unit. No brake tests were made on the vertical-wheel shafts but

the discharge from each was carefully measured over a standard weir by Mr. A. F. Sickman, hydraulic engineer for the Holyoke Water Power Company. The best efficiency of the wheels at full gate, which in this case includes the loss of gears and bearings, was 83.5 per cent and 83.7 per cent, respectively.

34 Several similar tests have been made with corresponding evidence as to good efficiency of the gears. In one plant, containing seven pairs of vertical wheels, where all the mortised wooden gears and cast-iron pinions had been in use for over fifteen years these were still good, without having had even a tooth changed.

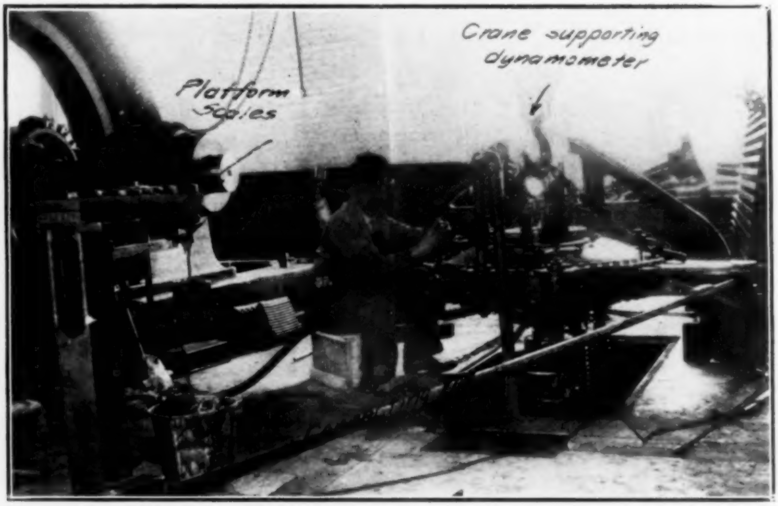

Fig. 10 Testing of Vertical Wheel (Gear Removed)

35 All of the information obtained concerning the loss due to bevel gear drives, leads the writer to conclude that if gears are properly designed, set up, and operated, and are not overloaded intermittently or continuously or left to care for themselves, they should show an efficiency of from 95 to 97 per cent.

36 Figs. 11 and 12 show two settings in which the wheels were tested after installation. The results of the tests, together with the results of the tests on the same wheels at the Holyoke testing flume, and reduced to a common head-basis, are given in the curves, Figs. 13 to 16 inclusive.

37 The setting shown in Fig. 11 is for a pair of 36-in. wheels operating under a head of 28 ft. at a speed of 200 r.p.m. The wheels are

set 3.3 diameters apart and the draft tube changes from a circular to an oval cross section with a constantly increasing area, and discharges horizontally into tail-race. In this particular installation, the velocity of the departing water from the draft tube was found to increase materially the working head on the wheels. The results of the brake tests made after installation, as shown by the accompanying curves, checked with the Holyoke tests computed for the same head at full gate. It may also be of interest to note that the generator tests made immediately following also checked with the brake tests. The difference between the two tests as shown in the curves at part gate openings is probably due to different methods of setting the gates under test. The full gate opening, however, was exactly alike in both cases.

38 In the setting shown in Fig. 12 the wheels actually give a considerable increase in power over that computed from the Holyoke tests. This is probably due to two reasons, the first and most important being that the Holyoke testing flume is not designed to test wheels of this size; and second, that the setting is exceptionally good. The wheels are 48 in. in diameter and are set 4.25 diameters apart with ample space around the wheels in the casing and with well-proportioned center case and draft tube. The curves in Fig. 15 and Fig. 16, representing the results of tests made on these wheels both at Holyoke and after installation, show that the best speed at full gate as computed from the Holyoke tests is about 182 r.p.m., and the best speed after installation 195 r.p.m. Comparison of the horsepowers at best speed shows an increase after installation of 40 h.p., but if the horsepowers at 195 r.p.m. be compared, then there is an increase of 130 h.p. This apparently excessive increase in power is to a large extent due to the fact that the best speed after installation was 195 r.p.m., while from the curve of the Holyoke test the power at 195 r.p.m. has materially dropped off.

39 The curves in Fig. 17 and Fig. 18 show the results of tests on a pair of 45-in. wheels under a head of 44 ft., with a normal speed of 200 r.p.m. It is seen that the discharge increases with the gate opening but the power begins to drop off at 0.75 gate opening and remains contant from 0.9 to full, which accounts for the efficiency curve dropping off so rapidly. In this installation the wheels were set too closely together (less than three diameters apart) and the shaft was excessively large. In accordance with data obtained from our recent tests these wheels should have been set at least four diameters apart.

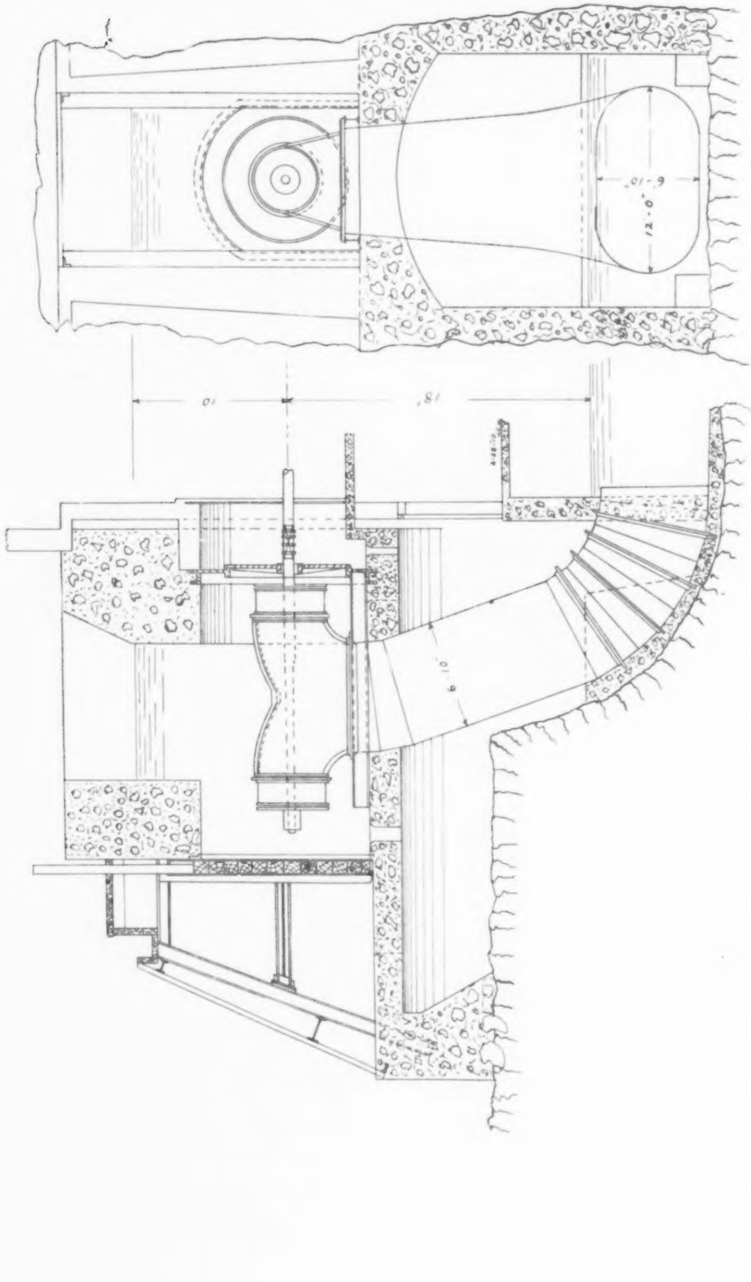

Fig. 11 Setting of a Pair of 36-in. Wheels under 28-ft. Head. Distance Between Wheels 3.3 Diameters

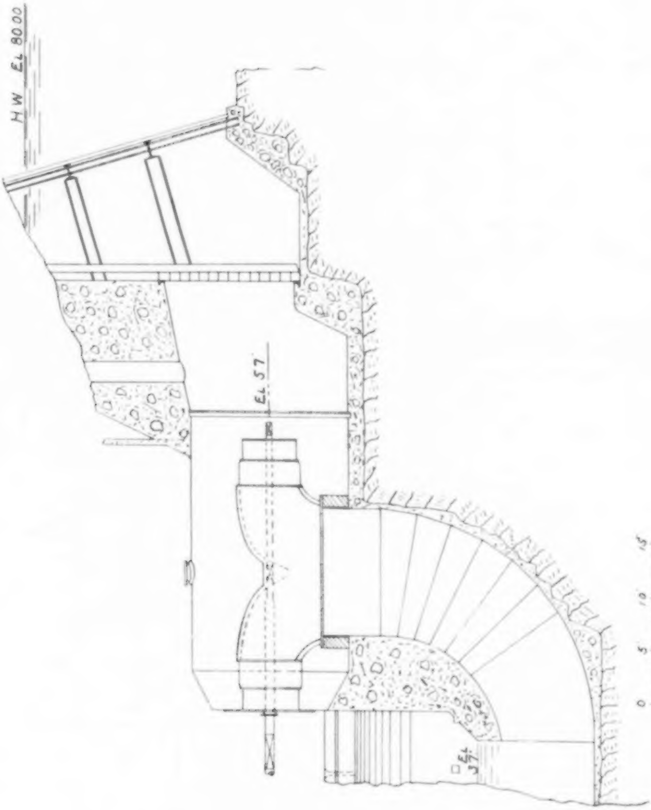

FIG. 12 SETTING OF A PAIR OF 48-IN. WHEELS UNDER 40-FT. HEAD. DISTANCE BETWEEN WHEELS 4.25 DIAMETERS

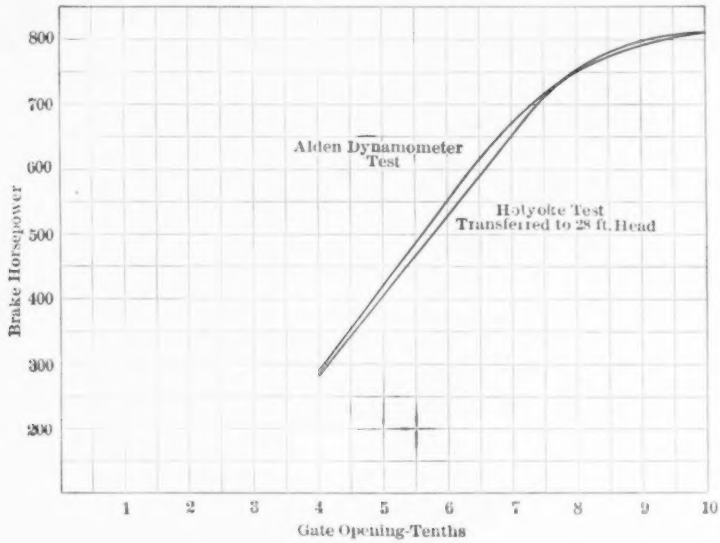

FIG. 13 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND GATE OPENING FOR A PAIR OF 36-IN. WHEELS UNDER 28-FT. HEAD AND 200 R.P.M.

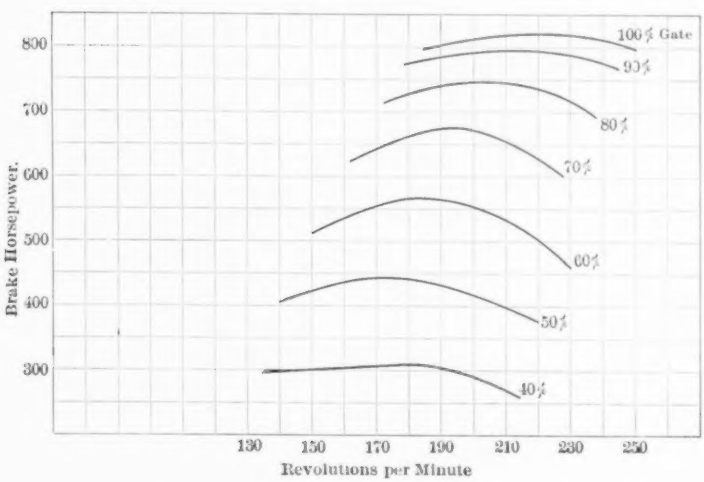

FIG. 14 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND SPEED FOR A PAIR OF 36-IN. WHEELS UNDER 28-FT. HEAD

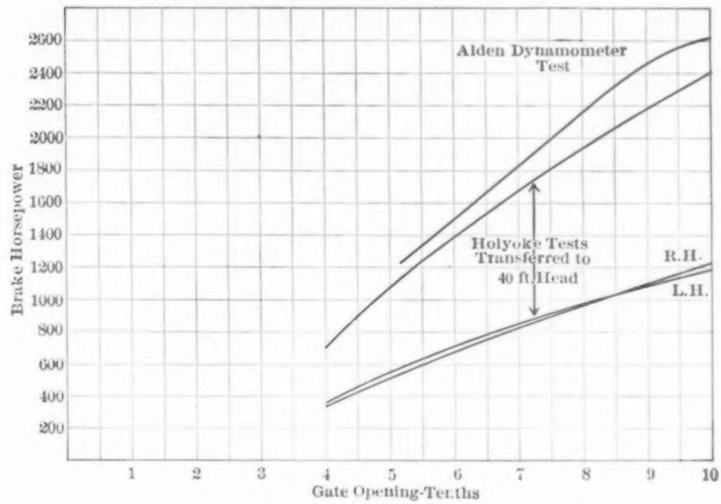

FIG. 15 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND GATE OPENING FOR A PAIR OF 48-IN. WHEELS UNDER 40-FT. HEAD AND 200 R.P.M.

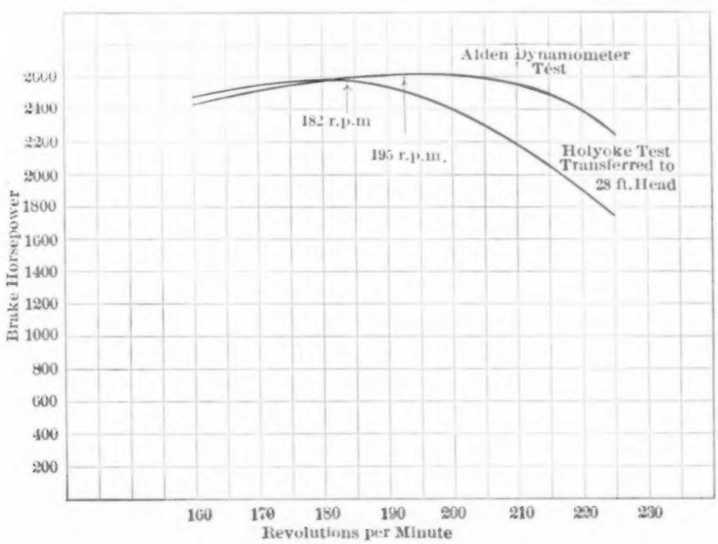

FIG. 16 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND SPEED AT FULL GATE FOR A PAIR OF 48-IN. WHEELS UNDER 40-FT. HEAD.

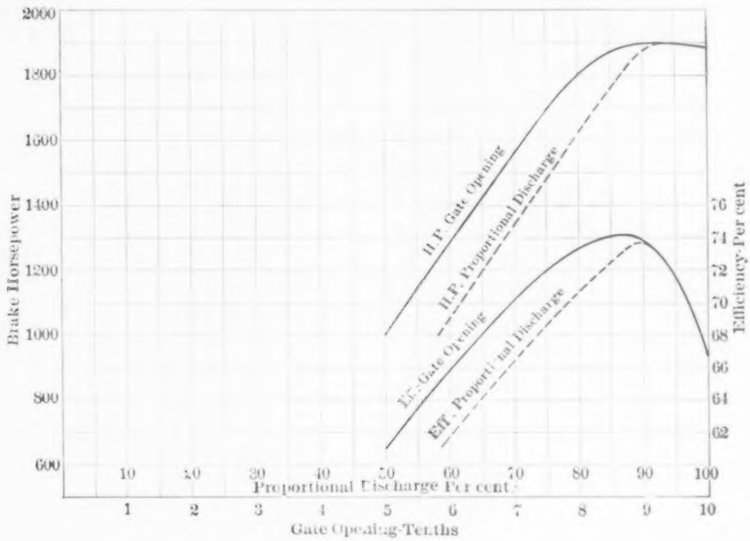

FIG. 17 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND GATE OPENING, HORSEPOWER AND PROPORTIONAL DISCHARGE, EFFICIENCY AND GATE OPENING, EFFICIENCY AND PROPORTIONAL DISCHARGE; PAIR OF 45-IN. WHEELS, 44-FT. HEAD AND 200 R.P.M.

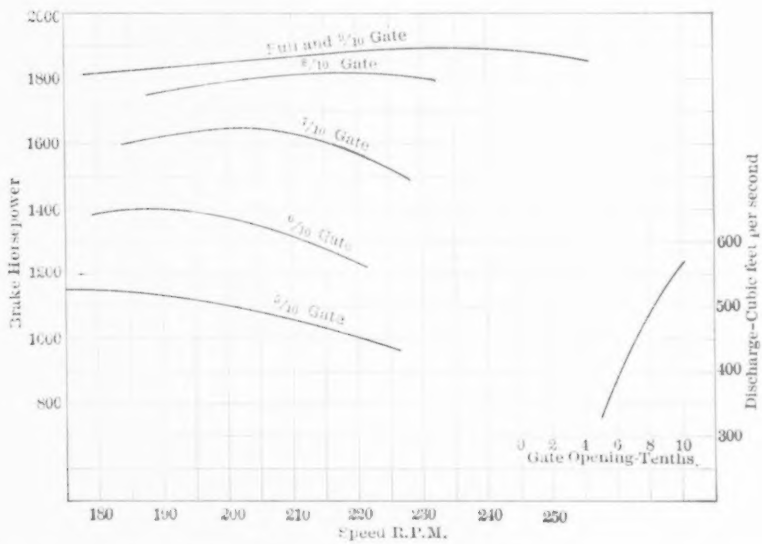

FIG. 18 CURVES SHOWING RELATION BETWEEN HORSEPOWER AND SPEED, GATE OPENING AND DISCHARGE; PAIR OF 45-IN. WHEELS, 44-FT. HEAD

40 While the tests on the 48-in. wheels shown in Fig. 12 are the best example that we have of large turbines actually showing more power when tested after installation than that computed from the Holyoke tests, it is by no means the only instance of such results. Within the past five years there have been made over 100 complete brake tests of wheels at different plants in all of the New England States and most of the Eastern Atlantic States. Most of the leading makes of wheels have been tested in this manner, and under heads varying from 10 ft. to 200 ft. Information derived from this experience confirms the following general statement:

41 That the performance of low-head turbines of diameters up to about 36 in., as computed from the Holyoke tests, should be attained after installation; that turbines greater than 36 in. in diameter should show better results after installation than those computed from the Holyoke tests, the amount of difference increasing with the diameter of the turbine.

42 There is still a vast deal of information needed concerning the behavior and proper settings of wheels after installation, before the subject can be put upon a good working basis, and it is hoped that enough points have been touched upon in this paper to call forth a goodly amount of discussion and reliable information that may be of value.

MECHANICAL FEATURES OF ELECTRIC DRIVING IN MACHINE SHOPS

By John Riddell, Schenectady, N. Y.
Member of the Society

It is with the mechanical features of motor driving that this paper is to deal, and chiefly with what has been done in the electrical equipment of the most commonly used machine tools in the plant of the General Electric Company, at Schenectady, with a few sketches of some large work that has been erected outside.

2 Some ten or twelve years ago it was decided to erect a large and up-to-date electrically driven machine shop, and plans were started some time ahead of the completion of the building. At first the plan was to have every machine tool individually driven, but the time was so short that we abandoned this idea and concluded to arrange the machines in groups, driven by a motor direct-coupled to the end of a section of lineshaft. This arrangement was used only to take care of small and medium-sized machines, of which few, if any, were at that time equipped with individual motors.

3 Considerable difficulty was experienced in arranging the lineshafts and countershafts in this system, owing to their being traversed by small side-bay electric cranes. Fig. 1 gives a general idea of this method of group-driving. However crude it may appear in the light of present practice, it was considered in its time thoroughly up-to-date.

4 One of the mechanical difficulties encountered in attaching individual motors to small machines was the unwieldy size of some of the earlier motors of small capacity. Sometimes the motor would be as large or larger than the machine and this feature was largely responsible for the prevalence of group-driving of small machines, even where the individual drive would have been preferred. Recent improvement in motor design has led to a great reduction in the size of motors for a given capacity, so that the 25-h.p. motor of today is not nearly so

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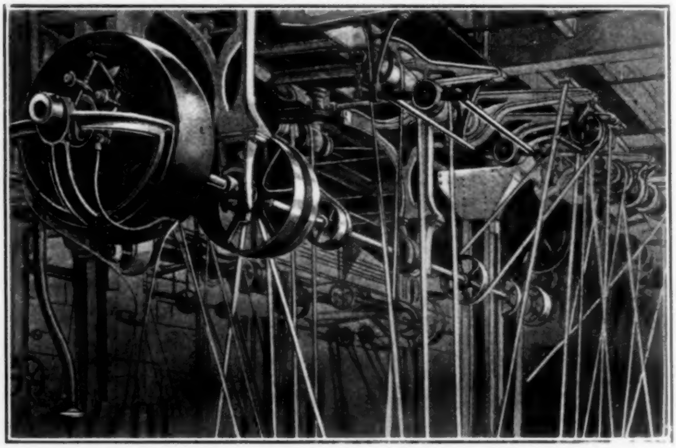

FIG. 1 METHOD OF GROUP-DRIVING

large as the 10-h.p. motor of earlier years. It is therefore much easier now to make the motor an integral part of the machine; and even where only fractional parts of a horsepower are required, for light operations,

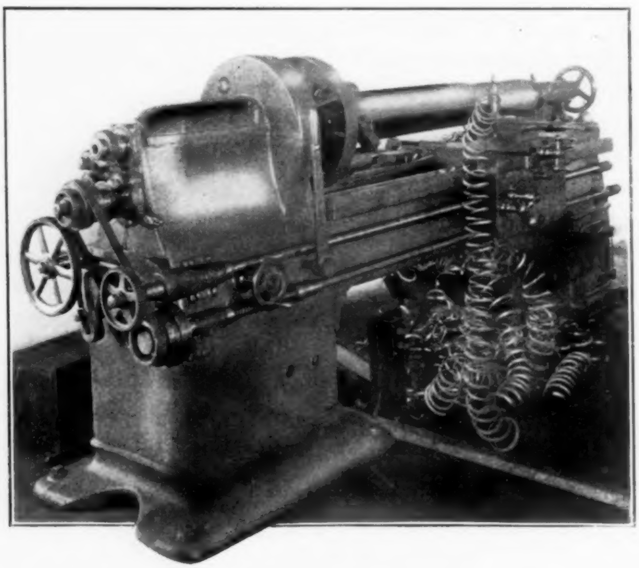

FIG. 2 LATHE DRIVEN BY INDUCTION MOTOR CONCEALED IN CABINET LEG

suitable motors of very small weight are now available which are well adapted in size to the smallest tools.

SMALL MACHINE TOOLS

5 Figs. 2, 3 and 4 show good examples of individual motor drives, in which the motors are inconspicuous and form integral parts of the machine tools. Fig. 2 shows a lathe driven by an induction motor concealed in the cabinet leg. Fig. 3 illustrates a wood-boring machine driven by an induction motor through a single pair of bevel gears. The inverted motor is bolted to a plate, which is in turn bolted to the

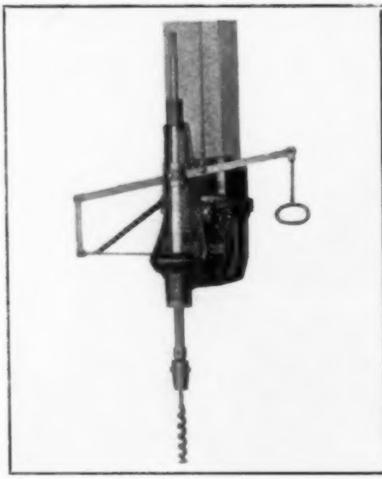

FIG. 3 WOOD-BORING MACHINE DRIVEN BY INDUCTION MOTOR, THROUGH SINGLE PAIR OF BEVEL GEARS

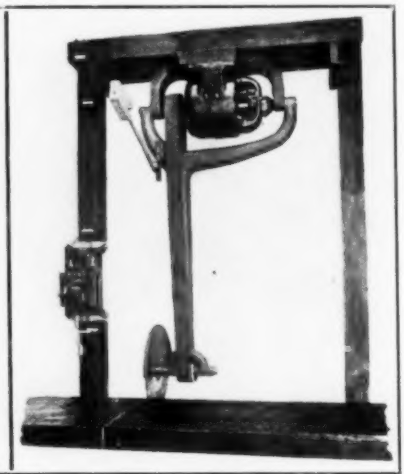

FIG. 4 24-IN. RELIANCE SWING SAW WITH MOTOR

bottom of a post and to the frame of the tool. At first, the plate was arranged to swivel on the tool post, in order to provide means for moving the tool longitudinally over the work; but later, this adjustment was abandoned, as it proved to be easier to move the work horizontally with reference to the tool. This tool is a good example of the compactness of the electric motor, and its easy adaptability to wood-working machinery. Fig. 4 shows the application of a direct-current motor to a 24-in. swing saw.

LARGE MACHINE TOOLS

6 The large lathes, vertical boring mills, planers, milling machines, etc., were supplied each with its own individual motor, which was a marked improvement over the original belt-and-countershaft methods of driving. Since starting this work, the company has changed over several thousand machine tools to motor drives. Most of the difficulties in changing from belt to motor driving were in making suitable

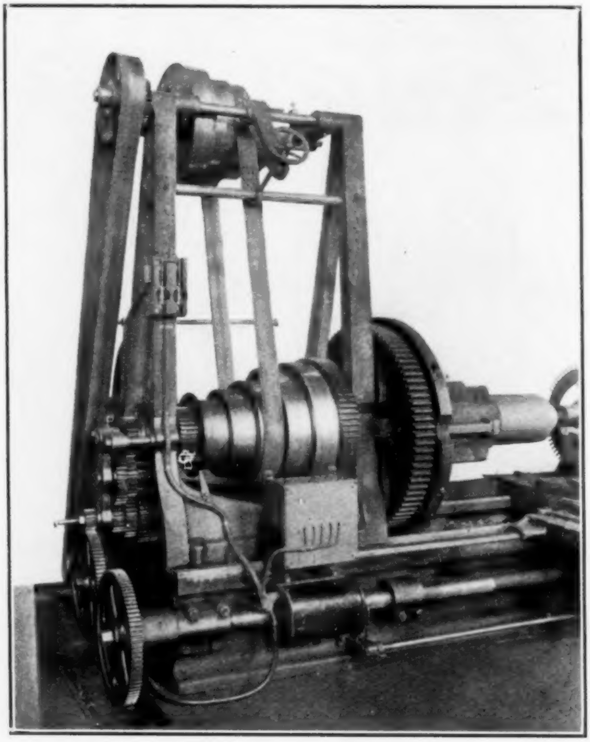

FIG. 5 42-IN. MILES-BEMENT LATHE DRIVEN BY CONSTANT-SPEED MOTOR USING CONES AND BELTS

connections between the motor and the tool to be driven. We do not pretend that in every case we have adopted the best arrangement, as in many cases the machine tool is not of sufficient value to warrant an expensive mechanical connection.

7 Take, for example, a medium-sized lathe of relatively moderate value. If an expensive transmission device was required in order to apply a motor to the lathe, the total cost of the lathe, as changed, might easily be more than the price of a new lathe especially designed for motor driving. In such cases it is found expedient to erect the countershaft and cone about four feet above the headstock, on suitable brackets, fasten the motor in a convenient place on the machine, and continue the use of cones and belts. Such an arrangement is shown in Fig. 5.

8 In all cases where old machine tools are converted to electric driving, it is desirable to mount the motor on some part of the machine

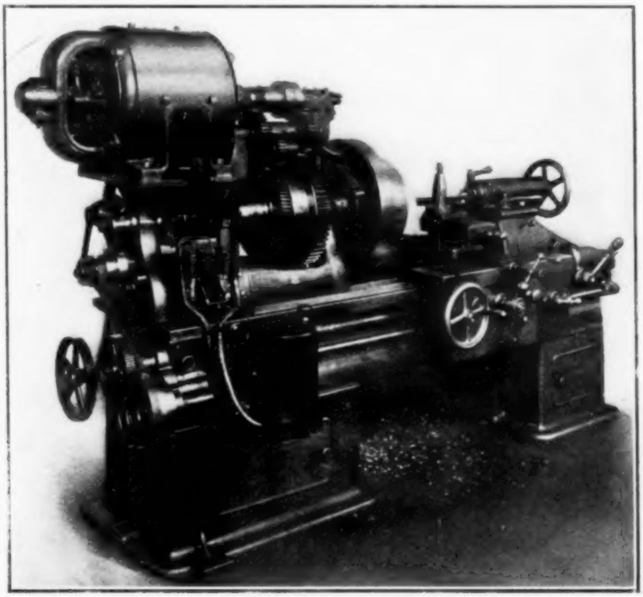

FIG. 6 24-IN. FITCHBURG LATHE DRIVEN BY MOTOR, WITH REVERSING GEARS

if possible, rather than on the floor near the machine. In the former case, the machine tool constitutes an independent self-contained unit which can be moved by the crane as a whole and located wherever desired. Cleanliness is promoted, by leaving a clear floor space to sweep, and the motor is less liable to accumulations of dirt caused by sweeping. There is also a tendency for the motor and the machine tool to become shifted out of alignment, if they are separately mounted on the floor.

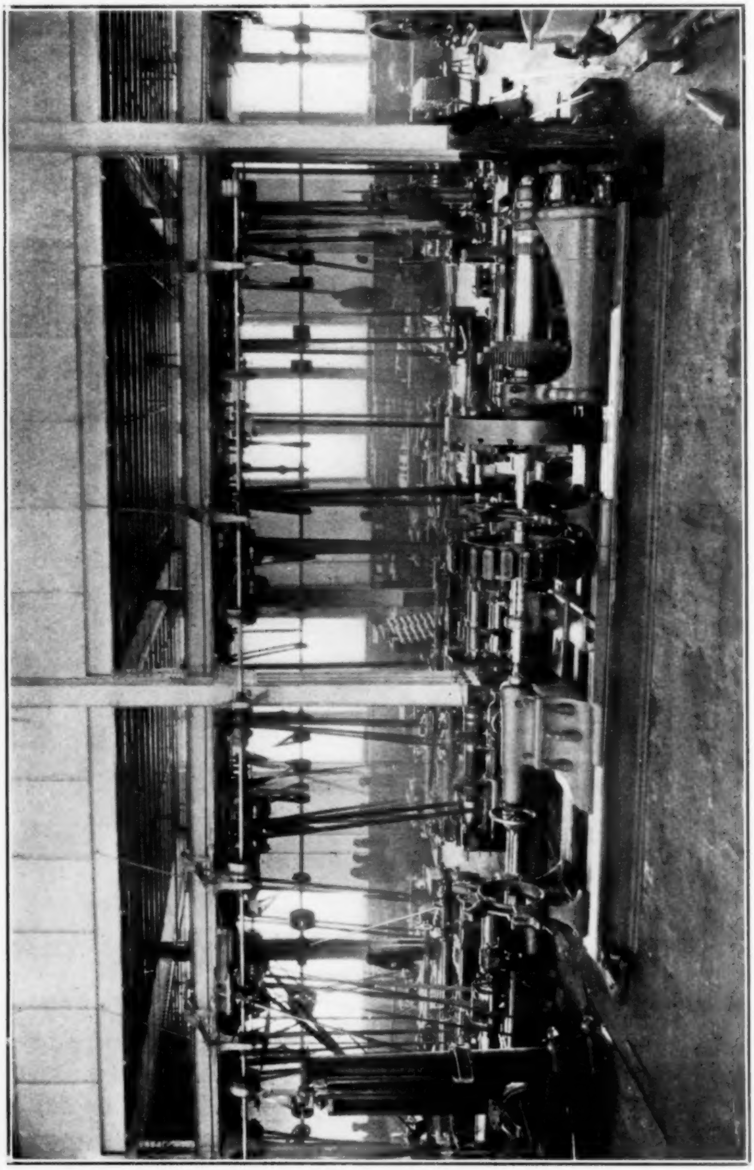

FIG. 7 LATHE, WITH MOTOR IN HEADSTOCK BENEATH SPINDLE

9 For lathes of more importance, and where the value of the tool warrants, we make an all-gear drive, with reversing gears, which are used principally for screw cutting. Fig. 6 shows a lathe equipped with reversing gears. More recently we have produced motors which can be very quickly reversed, obviating the necessity of reversing-gears.

10 When the original change was made from belt to motor drive there was one particular triple-geared lathe, 72-in. swing, to which we applied a two-to-one variable speed motor. The only change necessary in this case was to substitute two gears for the lathe cone, mounted on a quill, and made to engage with a pair of rocking gears on the motor. This gave a speed variation of four to one at the motor, and with the triple gears of the lathe, we had an exceedingly fine speed range. This lathe is shown in the foreground of Fig. 7. The motor is

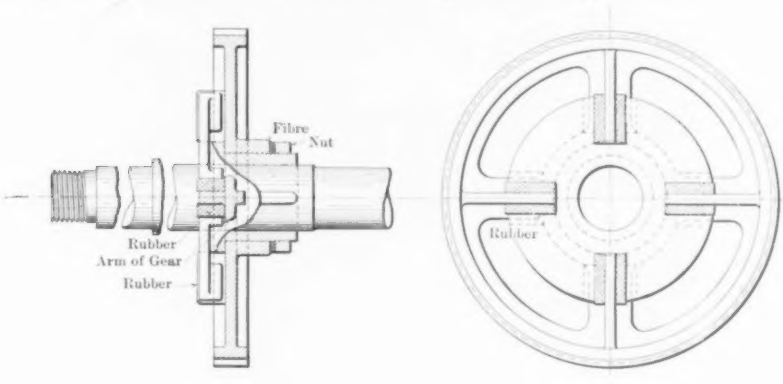

Fig. 8 Diagram of Device to Obviate Chatter Marks on Finished Work

placed in a most advantageous position, in the headstock underneath the spindle. During about ten years' service it has never been removed.

11 In a shafting department like that of the General Electric Company, where the range of size does not vary over three or four inches on the standard work, no very great speed changes are necessary, and a two-to-one motor usually has range enough to meet all requirements. What is particularly needed is ample power, strength of parts, and simplicity of construction, especially in lathes used for roughing, which are usually handled by unskilled labor.

12 For finishing shafts, however, where greater accuracy is required, an all-gear drive with steel gears is not satisfactory, because the chattering set up by the action of the gear teeth is very apt to be trans-

mitted to the finished work, leaving parallel ridges. This difficulty was overcome in some special lathes which we had built for the purpose, in which the driving gear on the main spindle was left loose and acted on the driving plate, keyed to the spindle, through four rubber buffers. This device is shown in Fig. 8.

13 More recently, trouble from this same cause was experienced in one of our tool departments, and was corrected by the use of a pinion made of muslin. This pinion has several features which specially adapt it to motor-driven machine tools. It is practically noiseless and

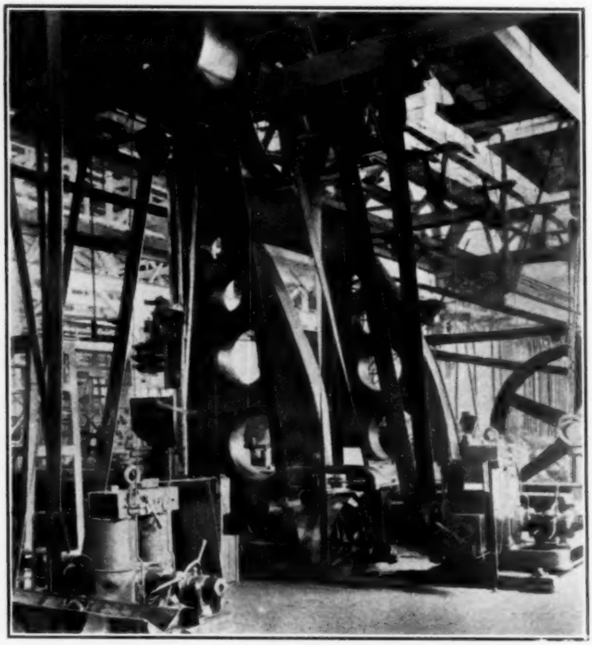

FIG. 9 EVOLUTION OF APPLICATION OF MOTORS TO PLANERS
LINESHAFT DISCARDED. COUNTERSHAFT DRIVEN FROM MOTOR ON FLOOR

very durable, does not shrink, and is sufficiently flexible and elastic to absorb vibrations which might be transmitted to the finished work.

14 Another application to motor driving in connection with lathes, and one that has been much appreciated, is the use of an auxiliary motor to operate lathe carriages having a long travel, of about 35 ft. The motor is bolted to one side of the carriage, and carries a pinion which meshes with the hand-wheel gear. A two-way switch is pro-

vided for operating the motor in either direction. The use of a motor not only saves the operator a difficult task, but it has also proved a great economy of time. It formerly required 30 to 35 minutes to shift the carriage through its full travel, and the hand wheels were placed so low that a man had to stoop to use them. The motor will move the carriage from one end of the lathe to the other in a minute and a half, and it can be stopped at any point within a 1/16 in. of the cut.

15 The best location for a motor on a lathe, and on most machine tools, is as low down on the machine as possible. The amplitude of the vibrations set up will be smaller, the closer the motor is to the floor, and the liability of chattering will therefore be reduced. The location of the motor in the cabinet leg, or in the headstock of a lathe, as shown in Fig. 2 and Fig. 7, is ideal, but there are, of course, many cases where the motor must be mounted over the headstock because no other place is available. The necessity of having the motor out of the way of the work is obvious, as turnings of chips, if allowed to get into the motor, would at once give rise to electrical troubles, especially in direct-current machines.

CONTROLLERS

16 The location and arrangement of controllers for lathes depend upon the class of work to be performed. Where the lathe is started, stopped, and varied in speed by the controller, the latter should be mounted on the front of the lathe, and the handle extended by means of a shaft to the lathe carriage, where it will be constantly under the hand of the operator. Ease of control unquestionably results in the rapid and economical production of work. Where the work varies considerably in diameter, frequent changes of speed will be required, and where the most efficient cutting speed can be obtained by simply turning a conveniently located handle, the work will be turned out at a maximum speed. If frequent shifting of belts is required, a great deal of the work will be done at less than maximum speed, owing to the extra exertion involved.

17 For lathes with constant-speed motors, operated with clutches and shifting levers, or machines on which continuous automatic operations are carried on, such as screw machines, the motor can be kept running for long periods without attention from the operator. In such cases the controller may be mounted at any convenient place on the machine, or near by on the floor, by means of a bracket.

PLANERS

18 Figs. 9, 10 and 11 illustrate the evolution of the application of motors to driving planers at the Schenectady shops. The first step, as shown in Fig. 9, was simply to discard the lineshaft and drive the countershaft from a motor placed on the floor. When this planer was operated by belts it was next to impossible to reverse it in a shorter space than about thirty inches, and even then with a great deal of wear and tear on the belts. Early in 1900 the company produced their first magnetic clutches for driving planers. The first of these clutches was applied to a Bement-Miles planer, 10 ft. wide by 20 ft. long. With this clutch, Fig. 10, we are able to reverse the planer prac-

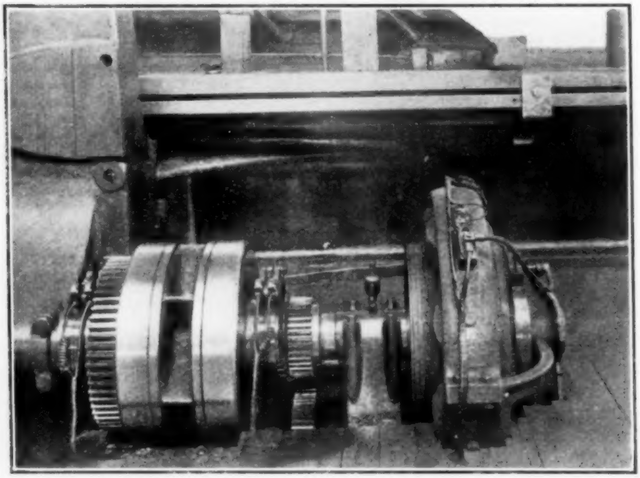

FIG. 10 EVOLUTION OF APPLICATION OF MOTORS TO PLANERS
MAGNETIC CLUTCH

tically to a line, and to reduce the space required for reversing to about 12 inches. Some trouble was experienced, however, with these first magnetic clutches, owing to the design of the magnets, and pneumatic clutches of a peculiar design were subsequently adopted and have been entirely satisfactory. Fig. 11 shows the arrangement of the motor and pneumatic clutch, as applied to the planer.

19 Our second lot of magnetic clutches was redesigned to eliminate the difficulties experienced with the first lot, and the new ones were applied to a number of portable slotters. These machines have been in continuous operation practically night and day up to the present

time. The clutches have operated with entire success, and I believe the magnetic clutch will eventually be found an important and efficient feature of transmission gears for planers and slotters.

VERTICAL BORING MILLS

20 In our original scheme for attaching motors direct to boring mills, an all-gear drive, with variable-speed motors, was selected, and with very slight changes, has been employed up to the present time. Fig. 12 shows a number of boring mills equipped in this way; the motors

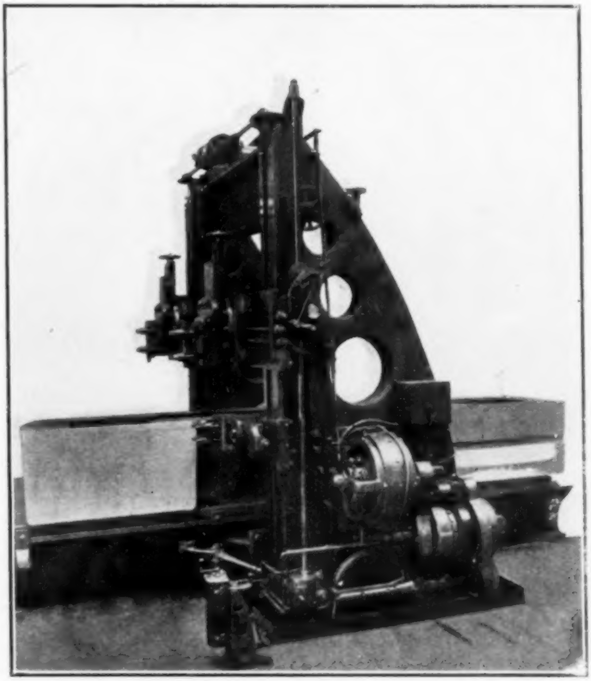

FIG. 11 EVOLUTION OF APPLICATION OF MOTORS TO PLANERS

COMPRESSED-AIR CLUTCH, TWO CONES

not being visible in the illustration because they are placed below the floor level between the side frames back of the revolving table. A solid foundation is laid, extending under the entire machine, a depression in the back between the side frames forming a bed for the motor, which is securely fixed in position. This common foundation makes the motor and the machine a single compact unit, and no additional

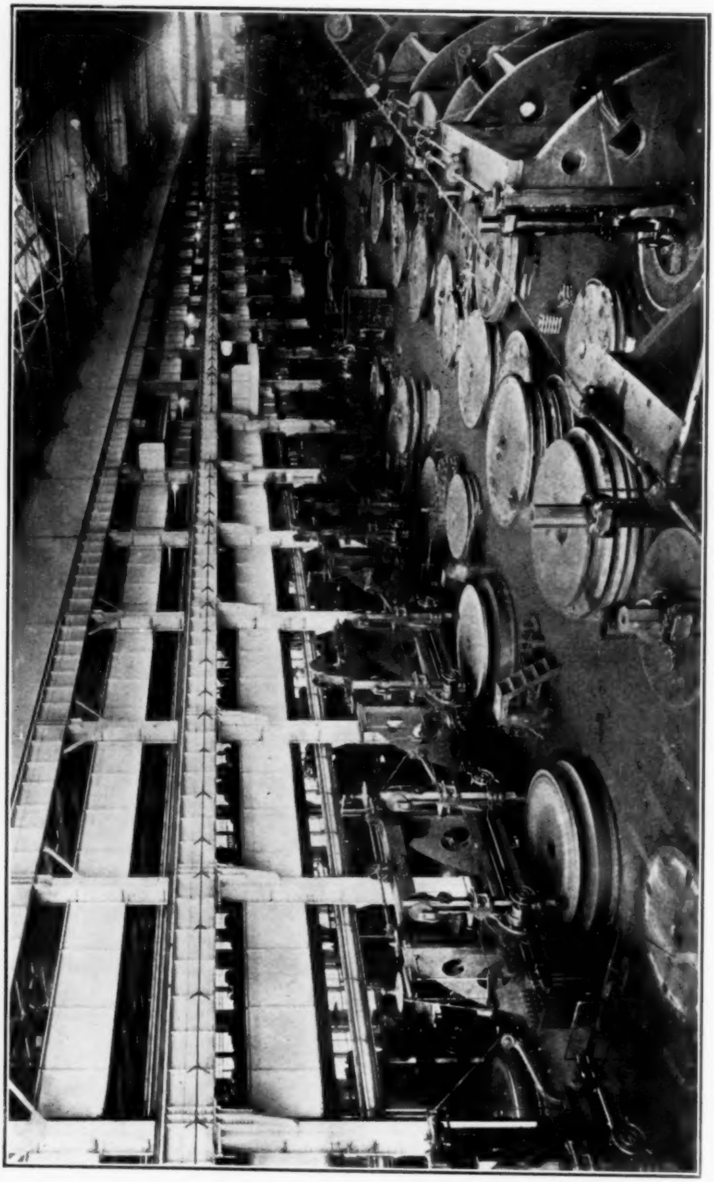

Fig. 12 Interior View of Building No. 60

floor space is required for the motor. No work put upon the table can interfere with the motor, the gears are entirely out of sight, and the controller is placed at the right-hand side of the machine, where the operator usually stands.

21 On boring mills from 20 ft. to 25 ft. in diameter, with the usual slow intermediate and direct-gear drive that comes with the mill, a variable-speed motor of two-to-one ratio gives a very satisfactory speed range.

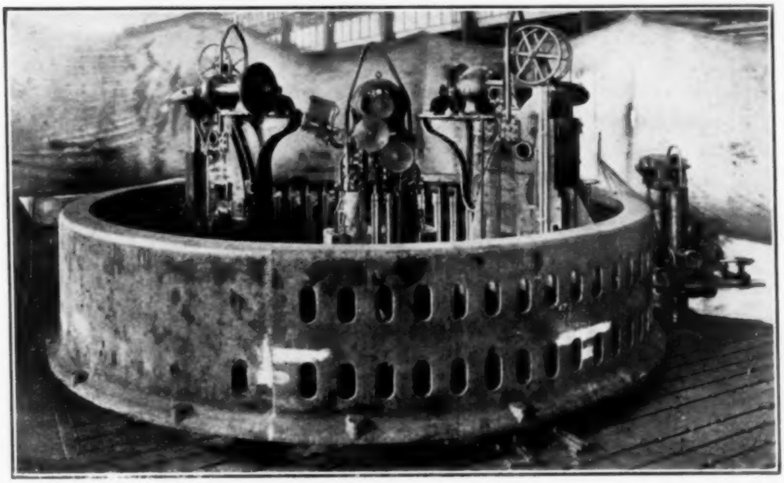

FIG. 13 APPLICATION OF MOTOR TO MACHINE TOOLS ON IRON FLOOR PLATE

PORTABLE TOOLS

22 Various machine tools of the portable type are used in ordinary large machine shops, and are placed in various positions on iron floor plates. The efficiency of these machines, such as rotary planers, slotters, etc., used in erecting departments, has been greatly increased by the use of electric motors. A group of these tools working on a large casting is shown in Fig. 13. The use of portable tools was almost impossible before the advent of the electric motor, but now the machine tools used in erecting shops, and in isolated places away from the source of power, when equipped with electric motors are ready to run at a moment's notice. On up-to-date rotary planers the motor is placed on the carriage; the under-side of the bases is planed, and means are provided for transfering the planers by electric cranes.

23 Under the old arrangement, if machinery stood idle for days and weeks, the countershafts and loose pulleys were so neglected that they would squeak; some one would then throw off the belts to stop the noise, and two hours' work was frequently necessary before they could be started for a hurried job. The same thing is true of some boiler makers' and blacksmiths' machines, such as rolls, shears, cutting-off machines, etc.

BELTING

24 Twenty-five or thirty years ago, in the days of the old jobbing shop, the buildings were not so high-studded, and the lineshafts and countershafts were usually within reach of a twelve-foot or fifteen-foot ladder at the most. Cone belts running to machine tools were very easily manipulated, and an expert lathe hand would never think of using a pole for shifting his belt from one step of the cone to another. But in these days of sanitary buildings, with ceilings from twenty to twenty-five feet high, it becomes an exceedingly difficult problem to arrange countershafts within reasonable heights; to say nothing of the necessary length of the vertical belts, the dust set in motion, and the difficulty of painting and whitewashing ceilings for the sake of cleanliness.

25 Another condition of lineshaft driving which has not been much spoken of, of late, is the difficulty of keeping the shaft in alignment, where the hangers are suspended from the roof trusses. The writer has seen such shafts five or six inches out of alignment, due to a heavy fall of snow on the roof, or to the settling of foundations. Another trouble is due to state laws and shop rulings, where a few trained men are employed as belt-lacers, and it is against the rules for men who are not belt-lacers to do the work. This is the cause of numerous delays, with consequent loss of production.

26 The only advantages that may be claimed for belts is that they take up the vibration of the gears, and thus prevent chatter marks on fine work; and that they will slip under over-load and be thrown off the pulley, stalling the machine, instead of breaking the tool or spoiling the work. It has already been explained how the effect of vibration has been remedied by means of rubber buffers or muslin pinions, and there are exceedingly few cases where belt-slip is not a detriment rather than an advantage. The use of high-speed tools calls for a considerable increase in the power necessary to drive the machines, as these tools take a heavier cut at a higher speed than those of car-

bon steel. These conditions make belt-slip very objectionable, and one of the chief advantages of motor driving is that it increases the power of machine tools beyond the capacity of belts of reasonable length. Modern practice is in the direction of eliminating the belt almost entirely, although there are a few machine tools, such as the older types of automatic-screw machines, grinding machines and some wood-working machines, on which they are necessarily retained.

27 The great majority of metal-working machines are best adapted to motor driving through all-gear connections, although a few machines, such as small grinders, buffing wheels, polishing wheels, etc., are best connected direct to the motor shaft.

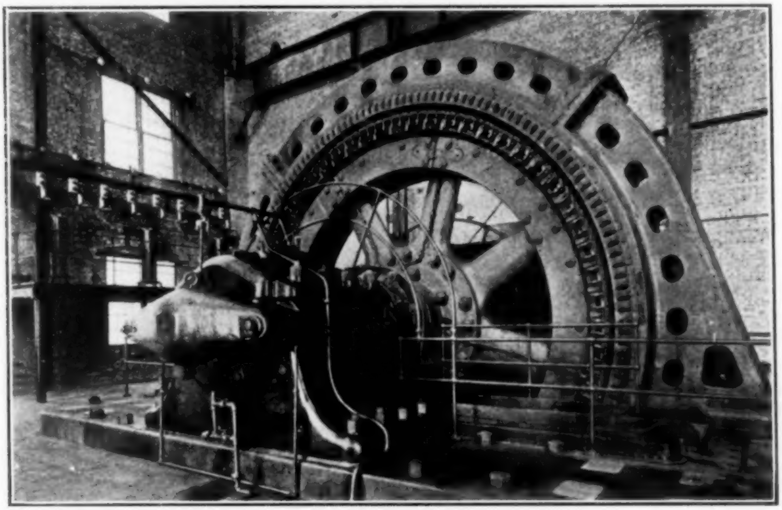

FIG. 14 6000-H.P. INDUCTION MOTOR, RAIL MILL, INDIANA STEEL COMPANY GARY, IND.

STEEL MILL WORK

28 The application of motors to metal-forming machines, such as rolls for rolling steel, charging cranes, etc., does not belong strictly to machine-shop practice, but the work of these machines is closely allied to what is required of other metal-working machines. Some of this work now performed by motors, is the heaviest kind of mechanical work ever attempted by any kind of prime mover. Fig. 14 shows a large induction motor driving an up-to-date steel rail mill, requiring 6000 h.p. or more. The operation of an entire mill is fre-

quently dependent on the continuity of operation of each piece of apparatus. For this reason it has been the practice to build the steam engines which drive mill machinery of the most substantial material and design. In replacing engines by electric motors, these same features were embodied in the motors.

29 The breakable coupling between the engine and the rolls is retained when motors are used. This coupling is of such strength that it breaks before the rolls are injured by shocks. The coupling frequently breaks diagonally, and a very heavy end-thrust is sometimes

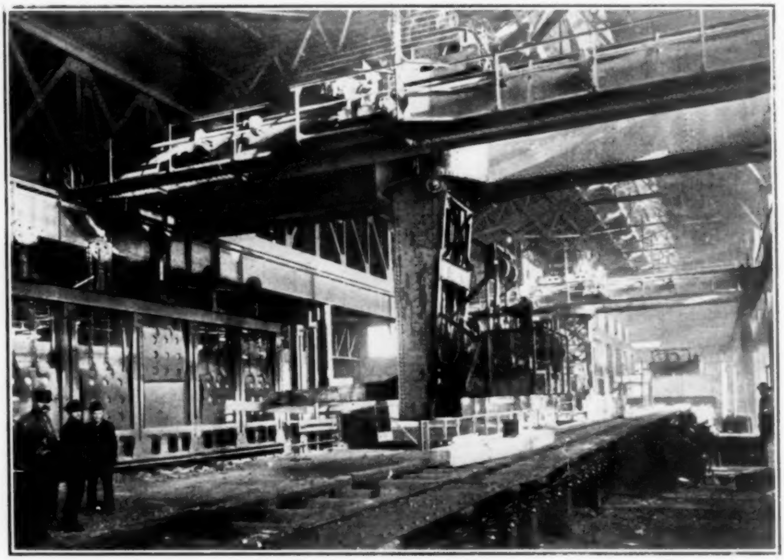

Fig. 15 Charging Crane, Blooming Mill, Illinois Steel Company, South Chicago, Ill.

produced, tending to separate the ends of the coupling. With the engine drive, this end-thrust frequently slides the roll housings out of their places, and considerable time is required to replace them. When motors are used, this difficulty is readily avoided by allowing the shaft of the motor to slide longitudinally in its bearings. To keep the motor shaft in its proper position, a breakable end-thrust bearing has been devised, which allows a bolt to break at a predetermined pressure before any other part of the machinery can be injured. This breakable bearing is shown in Fig. 14. It acts through the breakage of the long bolts shown alongside of the bearing housing.

The ready replacement of the parts when the coupling breaks is only one of the advantages incidental to the use of the motor for driving rolls.

30 Another style of motor, known as the mill motor, is illustrated in Fig. 15 and Fig. 16. It is used on slab-charging cranes, screw-downs, mill tables, etc., where it is subject to very rough handling, intense heat, severe over-loads, dirty surroundings, and other unfavorable conditions. All portions of these motors, such as the frame, shaft and bearings, are built unusually heavy to withstand safely the shocks to which they are subject.

31 There are thousands of other motor applications, which the writer will not attempt to describe. In the very complete paper by Mr. DeLeeuw, The Economy of the Electric Drive in the Machine Shop, are enumerated some of the important points in regard to applying motors to machine tools. The writer has, therefore, endeavored to confine himself to a consideration of these mechanical features not already covered.

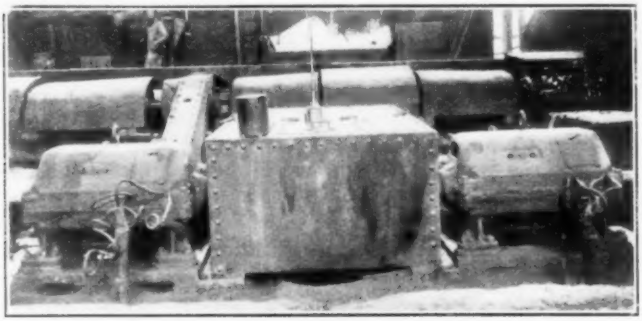

FIG. 16 TWO 50-H.P. D.C. MOTORS

32 At the Schenectady plant alone we have running some 8500 machine tools, of which 8150 are individually motor-driven. Group-driving has been adopted for some sensitive drills, speed lathes, and other small miscellaneous machines. Of the above tools there are 48 portable machines, consisting of slotters, milling and drilling machines, radial drills, etc. These machines are operated on 32,675 sq. ft. of iron floor plate, in addition to which there are 7000 sq. ft. of iron rails, cemented into the floor, for erecting purposes.

33 Had we continued our extensions since 1899, using lineshafts, countershafts and belting, we would have approximately 34,570 ft. of lineshaft, or about $6\frac{1}{2}$ miles, and about $4\frac{3}{4}$ miles of countershaft which would require about 21,225 hangers and bearings. Allowing two belts to each machine, with an average length of 25 ft. per belt, we would have for the 8500 machines a total of 425,000 ft. of belting, equal to about $80\frac{1}{2}$ miles.

DISCUSSION

AN ELECTRIC GAS METER

By Prof. Carl C. Thomas, Published in The Journal for December 1909

ABSTRACT OF PAPER

This paper describes a meter for measuring the rate of flow of gas or air which can be adapted for use as a steam meter or as a steam calorimeter, taking the quality of all the steam passing through a pipe instead of that of a sample of steam. The operation of the gas meter depends upon the principle of adding electrically a known quantity of heat to the gas and determining the rate of flow by the rise in temperature of the gas (about 5 deg. Fahr.) between inlet and outlet. The meter consists of an electric heater formed of suitable resistance-material disposed across the gas passage so as to impart heat at a uniform rate to the gas. The resulting rise of temperature is measured and autographically recorded by means of two electrical-resistance thermometers, one on each side of the heater. These consist of resistance-wire wound upon metal tubes so placed that all the gas passing through the meter comes in close proximity to the thermometers. The adoption of this principle of operation permits the construction of a very accurate and sensitive autographic meter of large capacity containing no moving parts in the gas passage; it is independent of fluctuations in pressure and temperature of the gas and capable of measuring gas or air at either high or low pressures or temperatures. The electrical energy required is about 1 kw. per 50,000 cu. ft. hourly capacity, at the pressures ordinarily used in gas mains.

DISCUSSION

Prof. L. S. Marks. The meter described by Professor Thomas should prove a valuable addition to the instruments used in gas engine and other testing. The possibilities of error in the indications of such an instrument must be fully examined.

2 This meter is fundamentally an instrument for determining the weight of gas or vapor flowing through it and is made to record volumes. It is obvious that these volumes cannot be those actually flowing but must be the volumes reduced to some standard conditions of temperature and pressure. The author has not mentioned this matter in his paper, but it is of considerable importance. A variation of 5 deg. fahr. in temperature, or of 0.3 lb. in pressure, under ordinary

atmospheric conditions, would result in an error of 1 per cent in the indications of the instrument if it were assumed to record actual volumes flowing. The calibration of the instrument by passing through it a known volume of a gas at known pressure and temperature, can easily be reduced to a calibration under standard pressure and temperature conditions.

3 In Par. 16 the author refers to the effect of water vapor carried in with the gas. He states that, in consequence of the small rise of temperature, the water vapor does not experience a change of state, and that, consequently, the latent heat of vaporization does not enter into consideration. It is obvious that he is considering here the case of a gas which not only is saturated with water vapor, but also is bringing with it minute particles of water in suspension. Under these conditions—and they are conditions which may easily obtain with blast-furnace gas which has just passed through the washers—the indications of the instrument will be rendered completely useless.

4 If the gas should enter at a temperature of 70 deg. fahr. it would contain 0.001148 lb. of water vapor. After passing through the meter with a rise of temperature of 5 deg. the same weight of gas could contain 0.001198 lb. of vapor; that is, there would occur a vaporization of 0.00005 lb. of moisture for every cubic foot of gas passing through the meter. The latent heat of vaporization at these temperatures is about 1050 B.t.u., or, 0.0525 B.t.u. will be used in converting the water into vapor. As the total heat required for raising one cubic foot of the gas 5 deg. fahr. is only about 0.1 B.t.u., we have here, obviously, the possibility of an error of the magnitude of 20 or 25 per cent in the indications of the instrument in the case suggested by the author where the gas is supersaturated with vapor.

5 The accuracy of the instrument depends primarily on the accuracy with which the volumetric specific heat of the gas can be determined, and upon the constancy of this quantity while the meter is in operation. For the correct determination of the volumetric specific heat it is necessary to know the volumetric composition of the gas and the volumetric specific heat of each of the constituents. The author has stated that the volumetric specific heat of each kind of gas is very nearly constant and the calibration of the instrument is based upon that assumption; that is, it is proposed to calibrate the instrument with, for example, producer gas, and then to use that calibration when the instrument is used at other times with producer gas. It will be interesting to examine how nearly correct this assumption

is. In the December number of The Journal of the Society there are given four analyses of producer gas, three of them by Mr. Bibbins, and one by Messrs. Garland and Kratz. I have worked out the volumetric specific heats of these gases, using the physical constants given by the author, and I have also taken at random two analyses from tests which I have made on a large anthracite gas producer. The results of the calculations are as follows:

6 For the two lignites in Mr. Bibbins' paper, the values of the specific heats are 0.01920 and 0.01899, which agree very closely with the average stated by the author. For the bituminous coal in Mr. Bibbins' paper, the value is 0.01899, and for the bituminous coal in the paper of Messrs. Garland and Kratz, the value is 0.0186. My own tests with anthracite give values 0.01826 and 0.01848, respectively.

7 It is quite evident from these figures that there is considerable variation, which may be as great as 5 per cent in the volumetric specific heat of producer gas. It may possibly be, as these figures seem to indicate, that the specific heat can be stated with greater accuracy if the type of coal is also specified, since there seems to be a relation between the volatile contents of the coal and the specific heat of the producer gas; but this point has not been sufficiently investigated to permit of any definite conclusions.

8 I have attempted also to see whether the value given for illuminating gas is constant. Only one illuminating gas was considered—that in Cambridge, Mass.—the analysis having been made by the chemist of the gas company. The specific heat calculated from this analysis is 0.02278. The specific heat calculated by the author is 0.02111. The value which he states as being practically constant for illuminating gas is 0.020. There is a variation of over 10 per cent between these values, so it would seem that it is not practicable to calibrate this instrument with illuminating gas at one place and assume it to be accurate when used with illuminating gas at some other place.

9 Moreover it must be recognized that such analysis as that given by the author for illuminating gas is only approximate; the heavy hydrocarbons are never fully analyzed and some kind of guess must be made as to their composition and specific heats. It cannot even be accepted as true that a calibration made with any particular illuminating gas will hold at some later date for gas from the same source. I have found variation in the composition of the Cambridge gas which would certainly cause a variation of two or three per cent in its specific heat.

10 It appears to me then, that this instrument cannot be accepted for accurate measurement unless analyses are being made of the gas that is going through the meter. In scientific testing, such analyses will naturally be undertaken and consequently the instrument should be extremely valuable in such cases. I would like to know what experience the author has had with this instrument in the measurement of volumes when the flow is variable as, for instance, when gas is flowing through a single-acting, four-cycle gas engine. In this case the flow will occur approximately for only one-fourth of the whole time of the test. The author's contention that the indication of the instrument would be accurate under these circumstances seems reasonable, but it would be valuable to know whether, and to what extent, his statement has been verified by actual investigation.

Prof. W. D. Ennis. I do not quite follow Professor Thomas' explanation that the proper correction has been made for fluctuations in the pressure of the gas. A change of, say, five per cent in the pressure, measured above the zero of pressure, would correspond roughly with a change of five per cent in the absolute temperature, without any addition whatever of heat. A change of five per cent in absolute temperature would mean a very large change in Fahrenheit temperature.

2 A more important point is suggested by the statement in Par. 4: "These thermometers consist of wire wound upon vertical tubes so disposed as to come in contact with all the gas passing through the meter, thereby indicating the average temperature over the cross section of the gas passage." If that is what the thermometers do, I question whether they indicate the average temperature of the gas, because more gas is passing at a point in the middle of the pipe than at points near the circumference. Do the thermometers indicate the average temperature of the whole weight of gas, which is the temperature that we must have in order to calculate the weight of gas flowing?

Edwin D. Dreyfus. Certain fuel gases—particularly blast-furnace, coke-oven and producer gas—carry with them a considerable quantity of finely divided solid matter, which in turn forms deposits in the piping or in any piece of apparatus through which the gas passes.

2 From their construction, it would seem that the grids in the meter would favor the formation of deposits of this sort, and I would like to ask whether Professor Thomas has made any trials to deter-

mine what effect, if any, such deposits have on the accuracy and general reliability of the instrument.

3 In cases where the gas is carried long distances through overhead mains—as in many blast-furnace plants—the temperature of the gas will be largely influenced by the temperature of the atmosphere, as between the summer and winter months the gas temperatures might easily vary as much as 50 deg., and the variation in temperature would have a decided effect on the moisture content. It seems probable that the moisture content of the gas is the most disturbing factor affecting the accuracy of the instrument. If this be so, then it is desirable that the actual significance of this factor should be determined by trials made over as wide a range of conditions as we may reasonably expect to meet in ordinary everyday practice.

A. R. DODGE. I would like to ask Professor Thomas if he has made calculations in regard to the amount of power necessary to operate this meter when used as a steam meter. The specific heat of steam being greater than that of gas and air, the amount of power required is considerable. For instance, Thomas meters on the large turbines of the New York Edison Co. would require about 545 kw. at normal load, quite a percentage of the total output of the turbine.

THE AUTHOR. Bearing upon the questions asked in the discussion, I would say, that in addition to the description of the meter given in the paper, I have given in Fig. 10 completed curves[1] showing the results obtained in calibrating the meter with both illuminating gas and air, reduced to standard conditions of 29.9 in. mercury and 62 deg. fahr. These curves show the method of using the meter for measuring directly standard cubic feet of gas or air at some convenient assumed conditions of pressure and temperature. In Par. 14, line 7 should read ". . . . at mean atmospheric pressure and 60 deg. fahr. . . ." The calculations in the table are for conditions of 760 mm. and 0 deg. cent. The results of measurement by the method described in the paper may be considered as given either in standard cubic feet, or in weight of gas passing the meter.

2 These meters are essentially applicable to the measurement of a dry gas or steam, that is, a gas or steam which is either saturated or superheated. Our experience with the gas meters has thus far been with illuminating gas and with air, and these are exceedingly easy of measurement. The gas or air we are measuring is saturated,

[1] Addition to paper, published in The Journal for January, 1910.

carrying its full quota of water vapor. The smallest quantity of heat introduced causes an immediate rise in temperature of the gas. If the gas carried a spray or mist of water, the measurement would be in error to a certain extent, because of the difference in specific heat between the water vapor and the gas. The extent of the error would depend upon the percentage of water vapor present.

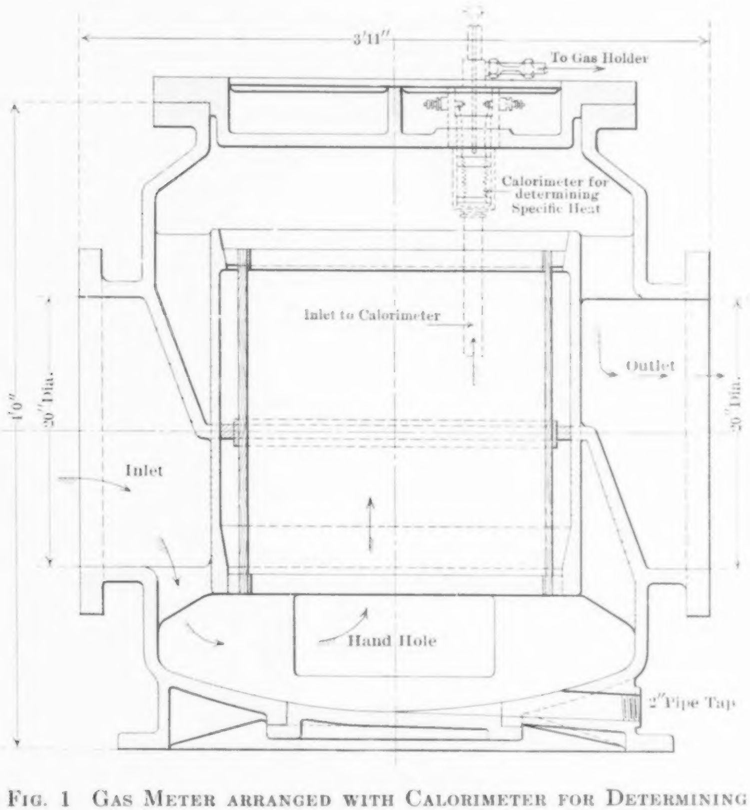

Fig. 1 Gas Meter arranged with Calorimeter for Determining Specific Heat

3 For gas or air under the conditions existing during the tests, of approximately 60 deg. fahr. and 29.8 in. mercury, and 6 in. water pressure, the correction for water vapor introduces a change in the results of less than ½ of 1 per cent, and has therefore been omitted. For other pressures and temperatures the correction for water vapor can be easily made by reference to the charts commonly used in gas works.

4 An interesting confirmation of the statement in Par. 16 is that the most minute addition of electrical energy to the gas or air causes an immediate rise of temperature.

5 Regarding variation of specific heat, the meter prover shown in Fig. 1, herewith, has been developed. It consists of a small electric heater which is placed in the outlet of the meter and discharges into a portable gas-holder such as is used for proving large meters. By this means a small known quantity of the gas is heated, and the specific heat actually determined by direct measurement. This determination can be made as often as desired until the variation of specific heat and satisfactory average values have been determined. So far it appears that the specific heat in a given installation is practically constant from day to day and from one time of day to another. The fact that it is possible thus to determine the specific heat experimentally affords a most valuable check upon the specific heat determined by calculation from chemical analysis, since the methods used in the latter are at best largely approximations.

6 As to dust and impurities collecting on the heater: A meter now in operation for some months has been used for measuring in the neighborhood of 100,000 cu. ft. per hr. of illuminating gas. The heater has been taken out once, and in handling it a small amount of grease was found on the heater material. Otherwise the interior of the meter was clean. In handling very impure gas it will of course be necessary to clean out the meter occasionally, simply in order to provide sufficient area for the passage of the required amount of gas. All the heat generated in the heater necessarily goes into the gas. The operation of heating and measuring difference of temperature is all accomplished in a very short length of travel of the gas. This perhaps answers the question regarding the heat-insulating effect of deposits which may be formed on the heater. The rise of temperature of the material of the heater is only 15 or 20 deg. fahr. This temperature rise might be effected by a considerable deposit on the heater, but the heat generated must necessarily be liberated from the heater and given up to the gas, resulting in no error in gas measurement.

7 As to variable flow, the best evidence is presented by the curves and calculations on the chart. The entire regularity of operation, during experiments conducted under circumstances very favorable to accuracy of observation seem to show that no error is introduced by non-uniformity of flow. If such a cause of error existed, it seems probable that it would have been found during experiments such as have been made with this meter, covering the wide range of from

6000 cu. ft. to about 127,500 cu. ft. per hr. The meter is now being built so that the gas passes in a vertical direction through the heater and thermometers, and this would seem to favor regularity of distribution over the cross section of the passage. The change from horizontal to vertical position was however dictated by convenience of attachment and in order to obtain accessibility, although it seems favorable to the above-mentioned consideration.

8 During the air tests extensive fluctuations of pressure took place, due to the pulsations of the blower supplying the air. These were so great at times as to cause the water to be thrown completely out of the pressure gages, but the results obtained remained entirely regular, as shown on the chart. A small meter has been used on a single-acting three-cylinder four-cycle gas engine delivering from 30 h.p. to 60 h.p. The meter was constructed of sheet iron, and although the pressure fluctuations were such that the sides of the heater "panted" continuously, the measurement of gas was accurately accomplished.

9 Answering Mr. Dodge's question regarding the amount of energy required to measure steam with these meters, we are using 5 deg. fahr. temperature difference, which can be measured to an accuracy of 1 per cent and the energy required is 1 kw. per 1000 lb. of steam per hr. Taking a water rate of 12 lb. per h.p.-hr., 1 kw. would measure the steam used for about 80 h.p.

10 Stated generally this meter seems to be particularly suitable for the measurement of dry saturated or superheated gas, air or steam. The substance to be measured should be dry, but it may be of any pressure and temperature which the materials of construction will stand, and the measurement is independent of fluctuations of pressure and temperature. The recording mechanism can be placed in any convenient position, as, for instance, in an office, instead of near the meter, and the graphical record is thus continually observable. It is not necessary that a graphical record should be taken. An ordinary integrating wattmeter showing the amount of energy it has required, to maintain the constant temperature difference of 5 deg. between inlet and outlet of the meter, suffices as a record of rate of flow, though the variation is best shown by an autographic record

GOVERNING ROLLING MILL ENGINES

BY W. P. CAINE, PUBLISHED IN THE JOURNAL FOR MID-NOVEMBER

ABSTRACT OF PAPER

The paper describes first the types of rolling mills and the engines driving them; analyzes the distribution of power, the design and the peration of the engines, calling attention to causes of low steam economy, high repair charges and the danger of broken flywheels; describes and gives indicator cards and speed curves of a Corliss engine driving a three-high mill under two different conditions of governing, (*a*) under the widest range of adjustment of cut-off, (*b*) under a limited range, increasing the economy and making the engine run much more smoothly and safely. It also gives the reasons for the different results shown. A table is given showing the power required for rolling in the mill and the momentary source of the energy, whether from the cylinder or flywheel. A diagram shows this graphically. A description is also given of the tachometer used to take the speed curves.

DISCUSSION

HENRY C. ORD. The conservation of energy as applied to rolling mills has received very little attention until during the past five or six years. The power required to roll a given piece was not known until the continuous indicator and recording tachometer were applied. The cards from these instruments furnished records from which the conditions for any stage of the operation could be calculated, giving complete information as to the variation in power and speed for different conditions and classes of work.

2 Rolling mill engineers have several reasons for preferring the two-high mill. As Mr. Caine says: "The engine uses steam only when the piece is on the mill." As there is considerable time between pieces in some classes of work, this is an important item. Should a piece not enter properly and stick in the rolls, thus stalling the engine, it is easy to reverse and back out the piece. This condition with a three-high mill would cause considerable trouble and delay. This is the reason why some of the modern three-high electric-motor-driven rolls are fitted with an emergency reversing de-

vice. The reversing feature can also be used as a quick safety-stop in case of accident.

3 The two-high mills are not so complicated as the three-high mills, and they have less rolls and no reversing mechanism for raising and lowering the table. In considering the two systems, this is an item of power that should be charged to the three-high mill. However, power is not the only consideration; it is usually a question of the maximum tonnage in minimum time with the least amount of power.

4 The 25,000 h.p. engine Mr. Caine refers to is a 42 in. and 70 in. by 54 in. twin tandem horizontal compound-condensing blooming-mill engine, designed by the writer about four years ago, and built by the Allis-Chalmers Company for a blooming mill requiring an average of about 6000 h.p., which is also about the economical load for the engine. It was designed for a maximum of 25,000 h.p. under the following conditions: steam pressure, 150 lb. gage; cut-off, $\frac{3}{4}$ stroke; vacuum 25 in. referred to 30 in. barometer; r.p.m. 200. This machine has been described as "the world's most powerful engine." I believe the piston speed, 1800 ft. per min., is the world's record.

5 If the engine Mr. Caine has experimented on was tested under the same conditions as regards pressure and work, with and without the function of the adjusting screw, we would expect different results than those shown. The controlling device has no control over the engine before the load is increased, until the speed falls to that fixed by the adjusting screw. At this speed and power the engine will be doing the maximum work allowed by the adjusting screw; consequently this control can be applied only to engines that have a longer-range cut-off than is required for the greatest loads they have to carry. After the above conditions are studied, it will be evident that to prevent the engine's being stalled before reaching the latest cut-off for which it was designed, we would have to dispense with the services of the adjusting screw.

6 From a study of the speed curves in Fig. 2, assuming that the height of the governor varies approximately as the speed of the engine, it will be seen that had the adjusting screw been applied and adjusted for the maximum load or minimum speed, it would be in momentary control during the second pass, and from the speed curves given in Fig. 3, it is seen that it was in action for about the same length of time during the third pass. As it would take considerable time for sufficient change in the energy of the flywheel to produce the results claimed, we believe there are other reasons for the improved condi-

tions shown. When the adjusting screw is in control, the engine will slow down much more quickly than without it, and the engine would be stalled by a lighter load; it would also take more time to do a given amount of work.

7 As engineers prefer to have engines with some power in reserve to take care of the abnormal load, I believe they would hesitate before using any method of control that eliminates the reserve power of the motor to which it is applied.

8 From a study of the Indiana Steel Company's plant at Gary, Ind., it is evident that conservation of energy as applied to steel plants has received considerable study. The rolls are driven by motors, current being supplied by gas-engine generators.

James Tribe. In Par. 5, Mr. Caine refers to a certain engine capable of developing 25,000 h.p. while the average load does not exceed one-seventh of its maximum capacity. I do not know what engine he refers to, but a blooming mill engine of unusually large dimensions and answering somewhat to the description given, was built by the Allis-Chalmers Company and installed less than two years ago at the Carnegie Steel Company's South Sharon plant. This was a reversing engine for rolling 28 in. by 28 in. ingots on a two-high mill. The maximum power, or rather, the maximum possibility, of this engine, was likewise 25,000 h.p., which was also far in excess of its average load, but it is doubtful if there is in existence a more efficient reversing blooming-mill steam engine equipment.

2 In Par. 6, Mr. Caine asserts that in a three-high mill driven continuously in one direction, the energy stored in the flywheel would make it possible to do the same work with considerably less than one-half the power. There should therefore be some explanation to justify the installation of so large an engine, at so recent a date, and having so large a percentage of surplus capacity. There are two reasons for this: first, because of the stalling action at the moment the rolls bite the ingot; secondly, because of the probable increase of speed as the ingot is released.

3 The reversing engine, for well-known reasons, has no flywheel, consequently the momentum of the rotating parts is comparatively nothing. Therefore the stalling action at the instant of biting the ingot, due to the tremendous impact, which is followed immediately by an abnormally high tangential resistance at the rolls surface, creates a demand for an exceedingly powerful engine. It is just at this moment that surplus power, or reserve energy, is of the most

vital necessity in order to save time and heat which would otherwise be wasted while waiting for the engine to recover itself. At this critical moment the term "horsepower" does not explain the measure of effort necessary for overcoming this resistance; for as a less powerful engine would be almost, if not quite, brought to rest, two of the power elements, namely, time and space, are for the time being practically eliminated, and the engine reduced to a simple "force" acting on the crank pin. Hence, it becomes a question of a turning moment sufficient here to overcome the resistance, and of regaining normal speed in the shortest possible time: for loss of time means not only delay (which is very serious), but loss of heat, and loss of heat means additional power necessary.

4 In the second place, the engine must be so constructed as to be capable of permitting 25 per cent increase of speed above normal with perfect safety, for the reason that at the instant the ingot leaves the rolls, the slightest delay on the part of the operator in shutting off steam, all resistance except friction having been suddenly removed, results in an increase of speed and the safe limit is quickly reached. These two extreme conditions, full steam and abnormal speed, never occur at the same instant, in actual operation, but the engine must be capable of meeting them, and therefore such an engine may be said to be capable of several times its normal capacity.

5 So far as the gripping and the releasing of the ingot are concerned the effect is the same whether a reversing or a continuously running engine is employed; for the energy of a flywheel may to some extent prevent the stalling action, just as this is accomplished by the surplus capacity of the larger engine. But flywheel energy cannot be spent without a proportionate reduction in speed, and with loss of velocity more time must be taken to regain it than would be the case where the force of the steam is applied entirely in the mill. Part of the steam energy would be spent in restoring the wheel energy and consequently, more time would be consumed in the pass than is the case in a sufficiently powerful engine without a flywheel. This loss of time and heat partly offsets the apparent gain in economy of the smaller engine. But the more serious loss would be experienced in a three-high mill, in both time and heat, as well as the additional power required for raising and lowering the ingot to the two different levels for each succeeding pass. Considering the shortness of the passes in blooming-mill work, this delay would be a very serious loss.

6 It therefore seems to me that but little, if any, substantial advantage can be gained in heavy blooming-mill work by the three-

high mill so long as it is steam-driven. It also seems to me that the only hope of any improvement in economy over present practice will be in the use of the present two-high reversing mill, but driven electrically. In such an equipment, we would have the necessary power to avoid delay on gripping the ingot, the means for instantly throwing off the power at the release of the ingot, and also the continuously running steam engine with a sufficiently heavy flywheel at the generator.

E. W. YEARSLEY.[1] The value of the flywheel as a means to obtain constant load with intermittent work is well illustrated by Mr. Caine's experiments. This arrangement has been considerably developed in conjunction with electrically driven rolling mills. Where considerable speed variation is allowable, and there is a suitable ratio of pause to operation time, the flywheel may be applied to many drives with economy.

2 Economical considerations are at present of great importance in the steel industry. Engines used for driving rolling mills are usually excessive steam consumers. There is no doubt that their performance in this respect can be greatly improved, especially for continuously running mills. In my opinion the electric motor will be found more reliable and satisfactory for this work, and it will be desirable to confine the refinements necessary for great economy of prime movers to an electric generating station.

3 Mr. Caine's method of regulating the governor is somewhat analogous to that used for controlling the rate of application and the limit of electric current to a main roll motor, in order to obtain the similar results of more uniform load, less rapid speed variation, and protection of the driver. The tests show conclusively the improvement in steam consumption and performance resulting.

4 As the paper points out, the problem is considerably complicated by variation in the number of pieces passing simultaneously, also by variation of the interval between passes and its relation to the time of the pass, and in the temperature and composition of the material. A speed variation of from 12 to 20 per cent transferring from 23 to 36 per cent of the kinetic energy of the flywheel, has been found desirable. With a given torque, time of load, and interval, this speed change fixes the weight of wheel required. Data of power performance of rolling-mill drives are rapidly accumulating. This paper is an interesting addition to such information.

[1]Electrical Engineer, Midvale Steel Company, Philadelphia, Pa.

The Author. Mr. Ord seems to have the impression that there was a great difference in the work done in the two examples given. As a matter of fact, the area of the piece was the same in each case, on entering the first pass, and therefore, the total work for the four passes would be as their relative weights, 2680 lb. for Case A and 2550 for Case B; B having a slight advantage in weight, and A an advantage of 5 lb. in steam pressure, so that the work was practically the same in each case.

2 The valve setting was not altered between tests. The difference in the behavior of the engine was due to the adjusting screw alone; and now, three years after these tests were made, this screw is still in service. This method of engine control does not eliminate the reserve power; it does cut it down to a point where judgment says there is still sufficient reserve to answer all requirements.

3 Mr. Tribe asks the reason for building reversing engines with such a large surplus of power. Such engines are usually driving blooming mills, where it is no uncommon practice to roll about one-half of the total number of passes, from bloom to finished product, in one stand of rolls, the remainder being taken care of from three, four or more stands of rolls, so that the blooming mill must handle these passes in very rapid succession in order to get the tonnage. The engineer handles the throttle and reverse levers, and the roller, the screw-down and the table rolls. The screw-down adjusts the distance between the rolls; consequently it fixes the amount of reduction on the bloom and the load on the engine is proportional to the reduction.

4 The screw-down has no fixed limits for each pass, therefore it will be set in a very short period, according to the judgment, or lack of judgment, of the roller. The writer has timed these operations with a stop watch and found that quite often the adjustment was made in less than two seconds; that is, the time from the end of one pass to the beginning of the next. It is quite likely that the screw-down does not get located where the operator intended; if the reduction is less, the roller will make some other passes heavier because he does not wish to add two additional passes. From the calculated results, from continuous indication cards on an engine of this type, on a single bloom one pass was noted where no reduction was made, while another pass required nearly three times the average power. From this sort of operating conditions, coupled with the desire to get an engine that will not stall under any circumstances, it becomes very evident why there is a great surplus of power. This also calls atten-

tion to one of the features in favor of the three-high mills, namely, that the roll designer can distribute the work approximately equally on every pass, with the proper data at hand.

5 The fact that the reversing engine is man-governed is brought out. This practically places the speed limit at the rate at which it would run with a wide open throttle and nothing in the mill; which would far exceed 25 per cent of the normal. Speed curve A shows that our engines run at about 16 per cent above normal, and with curve B at but 10 per cent above.

6 Mr. Yearsley suggests that the principle involved might be applied to other than mill engines. The writer can cite an instance where this was done. Our company has two-crank flywheel hydraulic pumps which are started and stopped by an accumulator. When the accumulator would drop, the governing throttle valves would open wide and the pumps would run up to the speed determined by the fly-ball governors (50 r.p.m.), and when the accumulator reached the top limit it would shut off the steam, stopping the pumps very abruptly. This continual starting and stopping caused considerable trouble in keeping up the various adjustments, and pins ran hot at times. Upon my suggestion the engineer in charge adjusted the governing throttle valves so that they could be only partially opened, and as a result the maximum speed is just a little above the average, the pumps running almost continually at about 20 r.p.m., the trouble with hot pins is no longer experienced, the rod adjustments last several times as long, and it is my belief that the water valves must give less trouble.

EFFICIENCY TESTS OF STEAM NOZZLES

By Prof. F. H. Sibley and T. S. Kemble, Published in The Journal for Mid-November

ABSTRACT OF PAPER

The object of the tests was to determine the efficiency of various shaped nozzles with steam flowing from a given initial pressure to a known vacuum; also to determine the effect on the efficiency of changing the angle of divergence.

Two methods were tried out for finding this efficiency: (*a*) by first finding the pressure in the nozzle by means of a search tube placed axially in the nozzle; (*b*) by finding the reaction of the nozzle. This was done by suspending the nozzle in an air-tight box at the end of a flexible steel tube. The deflection of the tube caused by the reaction of the nozzle was measured by a calibrated spring. Friction was eliminated. Preliminary work was done to calibrate the springs, to determine the volume of flow of the various nozzles and to determine the pressure in the nozzle and the surrounding medium.

The results of the tests indicate: (*a*) that the reaction is affected by a difference in pressure between the muzzle of the nozzle and the medium surrounding the nozzle; (*b*) that the efficiencies of the various nozzles were determined within a probable error of 2 per cent: (*c*) that the efficiency is affected more by the smoothness of finish on the inside of the nozzle than by the exact contour of the nozzle.

DISCUSSION.

Prof. J. A. Moyer. The methods used in these tests are obviously much more accurate than the impact plate devices used by Lewicki in his experiments with De Laval noz:les and by others who have conducted similar investigations more recently.

2 The high efficiencies obtained may be surprising to some who have not followed the latest developments in the designing of steam nozzles. Results of this investigation confirm in general the results given by Steinmetz[1] and by the writer showing that the efficiency of a well-designed nozzle for relatively large, as well as for small, limits of pressure will be above 97 per cent.

3 However, in one respect the investigation is not as complete as it was hoped it would be. There are not enough data to determine the effect on the efficiency of varying the length of a nozzle: that is,

[1] The Journal, Am. Soc. M. E., May 1908, p. 628.

nozzles of different lengths, but with the same taper or angle of divergence, should be compared. However, the statement is made in the last paragraph of the paper that there is no appreciable difference in the efficiencies of nozzles 10, 11 and 12, which, however, do not have the same taper, but have the same *areas* at the throat and at the mouth. It is probable that all of these nozzles were longer than they should be to obtain the highest efficiencies. More data are needed about the best length of the nozzle for a given expansion. Lewicki's experiments cover the two extremes: nozzles which are obviously too short, and those which resemble in proportions the ones used in this investigation.

4 The error due to moisture in the steam could not readily be determined, and while it is probably not large, yet this uncertainty might have been avoided by using superheated steam. The reaction in a nozzle due to the flow of superheated steam is apparently constant for a varying amount of superheat. This can be shown by the usual thermodynamic equations for flow and velocity—which determine the impulse force of a jet—and by the experiments of Lewicki[1] on the flow of superheated steam through De Laval nozzles. It should be observed however, that when these tests were started, Knoblauch and Jakob had not yet published the values which we are now using for the specific heat of superheated steam, and for this reason alone it was desirable to avoid the use of superheated steam.

5 It has not been mentioned by the authors of this paper that their method can be used to calculate the *apparent* efficiency of any nozzle for any initial and final pressures. By measuring the areas of a nozzle at the throat and at the mouth or "muzzle," the expansion ratio in a nozzle is determined, and by means of empirical equations, due to Zeuner and others,[2] the ratio of the corresponding initial and final pressures giving the highest efficiency, can be obtained. This ratio of pressures would correspond to the condition in these tests where the terminal and box pressures are the same.

6 If the ratio of the initial to the final pressure has been determined, either of these pressures can be readily calculated if the other is known. For example, if by measurement of the mouth and the throat areas, the expansion ratio of the nozzle is found to be, say, 3, then the ratio of the initial to the final pressure must be nearly 13.3 for the maximum efficiency of the jet discharged from it. For

[1] Mitteilungen über Forschungsarbeiten, Heft 12, Zalentafel 9 (*c*). Verein deutscher Ingenieure, 1904.

[2] J. A. Moyer, The Steam Turbine, p. 40–41.

this nozzle, therefore, with an initial pressure of 200 lb. absolute, the final pressure should be 15 lb. absolute. From the equations given in Par. 4 of the paper, the theoretical reaction can be readily calculated from the available energy corresponding to the pressure limits. The change in reaction due to final pressures different from those for which a nozzle is designed is, then, according to the method presented here, the product of the area of the mouth of the nozzle, times the difference between the correct final pressure for the nozzle—in this case 15 lb. absolute—and the pressure in the box, or in practice the pressure inside the casing of a stage of a turbine. Since reaction and velocity are directly proportional—*with constant flow*—the apparent velocity of the jet will be increased or decreased in the same proportion as the reaction is increased or decreased.

7 In actual practice, however, this does not occur. It has been observed that if a nozzle is used which does not expand the steam sufficiently, there is not nearly so much loss in the velocity of the jet as when the nozzle is too wide at the mouth and "over-expands" the steam. In other words, it has been found that a nozzle which is about 25 per cent too large in area at the mouth, will give to the jet only 90 per cent of the theoretical velocity, while one which is too small by the same percentage will give within 2 or 3 per cent of the maximum efficiency obtainable with the pressures best suited. All this involves something which is not taken into consideration in these reaction experiments; and for that reason, the results obtained by this method with varying back-pressures may possibly be misleading.

PROF. C. C. THOMAS. I have for years been interested in this line of investigation, and am glad to see this contribution. In Par. 26, the corrections which the authors make to the observed reactions seem to me to be somewhat open to question. Aside from this fact, I cannot quite see the theory upon which the corrections are based; the fact that the pressures vary considerably in all but perfect nozzles, from the center to the walls, and that very considerable irregularities of flow are found in nozzles, makes me doubt the necessity for making these corrections to the observed reactions.

STRICKLAND L. KNEASS. The tests appear to cover ordinary straight-tapered nozzles, as follows: 1 in 6, 1 in 5.77, 1 in 5, 1 in 4 and 1 in 3. In several cases the net areas vary slightly from these ratios owing to the displacement of the cylindrical search tube, but

the ratio of the throat area to the outlet area is practically the same for all nozzles, so that the results relate chiefly to the effect of the length of the tubes and the friction upon the walls.

2 From Table 5 it would appear that nozzle No. 13, which has a taper of approximately 1 in 4, gives a much higher efficiency between 100 lb. and 145 lb. absolute, than nozzles Nos. 9, 11 and 14, with tapers ranging from 1 in $3\frac{1}{2}$ to 1 in 6. As far as the knowledge of the writer extends, there is no logical reason for this result, and he would attribute the higher percentages to greater precision in the experiments rather than to any inherent efficiency in the 1-in-4 nozzle.

3 The correct contour of a nozzle for the discharge of elastic fluid is still a moot question. After an extended series of experiments between the years 1888 and 1891 with steam nozzles of various tapers, the writer offered the suggestion that the section should be in the form of a reversed curve, somewhat as shown in Fig. 1 here-

Fig. 1 Suggested Form of Nozzle

with. This curve was based on the theory that the acceleration should be constant during the passage of the steam through the nozzle, and that the areas at the several sections should be unit distances apart. These sections were calculated with due allowance for the change in the specific volume of the steam during expansion. The results obtained seemed to confirm this theory and were compared with the discharge from straight-tapered nozzles in a paper read before the Engineers' Club of Philadelphia in 1891. The writer's opinion was further corroborated by F. Hodgkinson before the Engineers' Society of Western Pennsylvania in 1900. In view, therefore, of published experiments upon nozzles of special contour for which advantageous results were claimed, it is surprising that the authors of this paper did not increase its value by widening the scope of their experiments, instead of confining their tests to the oldest and possibly less efficient form of tube.

4 Referring again to the experiments of the writer, his conclusions covered the general theorem that there was little difference

in the efficiency of the straight-tapered nozzle, so long as the terminal pressure of the steam within the tube was the same as that of the medium into which it flowed, and, further, that the terminal velocity would be the same under this given condition whether the taper were 1 in 6, 1 in 5, or 1 in 3. This opinion seems to be sustained by the authors, although the results are not satisfyingly definite, because different terminal pressures were used with each initial pressure and the table does not contain the terminal pressures within the nozzle, so that the comparison cannot be made with the pressure of the final medium.

5 It is desired that this point be emphasized, for a slight difference between these two pressures has an important effect upon the results. It is thought that a more exact method of determining the relative efficiency would have been to modify the length so that the terminal internal and external pressures would always be the same, for when an attempt is made to introduce minus or plus reaction for correction, doubt is thrown upon the result. This is especially obvious to any one who by careful observation of the flow of steam through and from nozzles of different proportions, has noted the unstable equilibrium of the jet when the terminal pressure of the medium exceeds that within the end of the nozzle. Some of the minor discrepancies may be charged to this item and the writer is somewhat skeptical as to the accuracy of the results obtained in practice when calculated under the theorem given in Par. 26.

6 It would have been interesting if the authors had recorded new data relative to the action of the steam within the nozzle and determined the terminal specific steam volume. The writer maintains that the specific gravity of steam at different sections of the nozzle does not correspond to that calculated by the thermo-dynamic equation, and therefore would be glad to have the authors state if the velocity of the steam, as given in Tables 3 and 5, is equal to the specific volume based upon the adiabatic equation, divided by the cross-sectional area.

7 A test of this kind should give the initial condition of the steam. The authors state that a thermometer was placed in a well at the rear of the nozzle, but there are no figures in the table giving the percentage of moisture. An objection to the construction of the apparatus can be offered in the liability of condensation of steam in the vertical flexible supply pipe. The steam flows downward under pressures varying from 100 lb. (328 deg. fahr.) to 145 lb. (356 deg. fahr.) and is surrounded by steam at a pressure

of 28 in. vacuum (100 deg. fahr.) so that a certain amount is sure to be condensed.

THE AUTHORS. It appears to be a generally accepted fact that under-expansion in the nozzle is preferable to over-expansion. Stodola's Theory of Steam Shock and his search-tube experiments point very decidedly in this direction Reaction experiments may even *appear* to indicate that under-expansion in the nozzle is in some cases preferable to using the theoretically correct ratio. This may also be true; but if the theory advanced in Par. 26 is correct, it is impossible to accept the results of any purely reaction experiments as giving a definite answer to this question; and where the pressure in the muzzle of the nozzle is not taken into account, all the results may be in error.

2 Of course, it is possible to calculate the muzzle pressure by theoretical and empirical formulae; but if we are to rely upon theoretical formulae there is no object in conducting tedious and expensive experiments. Moreover, empirical formulae on this subject are at least liable to be based in part upon reaction tests which have not taken into proper account the pressure in the muzzle of the nozzle. Also when the nozzle discharges into a pressure which is considerably greater than the theoretical muzzle pressure, violent fluctuations occur within the nozzle itself, so that the formulae do not apply and the results of reaction tests may become very misleading.

3 Par. 26 has been called in question from both the theoretical and the practical standpoint, so that a more extended consideration may not be out of order.

4 The first statement, "The reaction of any nozzle is equal to the summation of all the components, parallel to its axis, of the pressures within the nozzle and in the chamber from which it leads," can scarcely be questioned.

5 The net accelerating force F (Par. 4) which produces the velocity actually present in the muzzle of the nozzle may be divided into two parts. One part (call F_f) is a summation of components of the forces with which the internal walls react against the pressure of the steam. The second part is a force due to the pressure of the steam in the muzzle, and acts in opposition to the first.

6 Let F_m be this second part, P_m the muzzle pressure, and A the muzzle area. Then

$$F_m = P_m A$$

and

$$F = F_f - F_m = F_f - P_m A$$

Let R be the "true reaction of the nozzle," i. e., the force which is equal and opposite to F. Then

$$R = F = F_f - P_m A \tag{1}$$

7 The apparent reaction (called R_a) is the force with which the nozzle actually pulls or pushes in the direction opposite to the steam flow during the test. The apparent reaction of any nozzle is equal to the summation of the components parallel to its axis, of all the pressures, both internal and external, upon the walls of the nozzle and of the chamber from which it leads.

8 That part which is due to the internal wall pressure is equal to F_f. The external pressure acts, in the direction of flow of the jet, upon an area which is greater than that upon which it acts in the opposite direction, the difference being the area of the muzzle.[1]

9 Let P_e be the external pressure. Then

$$R_a = F_f - P_e A \tag{2}$$

Combining (1) and (2) we have

$$R = R_a = A \; (P_m - P_e) \tag{3}$$

10 The rest of Par. 26 accords with these equations.

11 It is evident from this that any acceleration or retardation of the jet beyond the muzzle (due to the pressure into which it is discharged or to any other cause) cannot affect the true reaction, and that so long as the conditions within the jet are stable so that the muzzle pressure can be properly determined, there is no danger of being misled except by a failure to make the corrections.

12 When the pressure into which the nozzle discharges is considerably greater than the theoretical muzzle pressure, such violent fluctuations ensue as to make all corrections impracticable, and the reaction tests under these conditions become worse than useless because they are misleading. The criticism by Professor Thomas is well founded with regard to such cases; but does not apply to the tests reported in this paper for the reason that these were all made under conditions which did not disturb the stability of the jet within the nozzle.

13 The fact that the corrected reactions shown in Fig. 13 and Fig. 14 lie in a horizontal line, i. e., are equal, is a further evidence that the theory upon which they are based is correct, also of the fact that the jet within the nozzle remained in very stable equilibrium,

[1] Gages connected to various points within the box showed that the external pressure did not vary in different parts of the box by as much as 0.01 lb. per sq. in. It must be remembered that the nozzle and the chamber from which it leads are here suspended within the box into which the jet discharges.

and that the creeping in of the external pressure along the internal wall had no practical effect, while the box pressure varied within the limits shown.

14 To show further the form of error involved in the failure to use these corrections, apparent and true reactions have been taken from Fig. 13 and Fig. 14, and the accompanying table computed.

Nozzle	I. p.	Flow Lbs. per sec.	Box t. p.	Reac.	Vel.	B. t. u.$_1$	B. t. u.$_2$ Table	Eff.
11	145	.1536	0.929	18.134*	3796	288.0	317.4	90.75
14	145	.1550	1.632	17.821*	3698	273.2	289.8	94.28
11	145	.1536	1.632	17.01†	3561	253.5	289.9	87.43
14	145	.1550	0.929	18.52†	3843	295.1	317.4	92.96
11	100	.1069	0.638	12.45*	3744	280.1	311.5	89.91
14	100	.1081	1.116	12.295*	3659	267.6	284.7	93.99
11	100	.1069	1.116	11.69†	3517	247.2	284.7	86.81
14	100	.1081	0.638	12.77†	3799	288.4	311.5	92.59

*Apparent and true.
†Apparent.

Data obtained from nozzles No. 11 and No. 14, with the box pressure equal to that in the muzzle of the nozzle, are given in lines 1 and 2. These velocities and efficiencies are the same as those given in Table 5, and require no correction for terminal pressure.

15 For line 3 the apparent reaction is taken for nozzle No. 11 with a box pressure which would be correct for No. 14, and the apparent velocity and efficiency of No. 11 are calculated from that basis.

16 For line 4 the apparent reaction for nozzle No. 14, with a box pressure which would be correct for nozz'e No. 11, is similarly used.

17 It was found in the experiments plotted in Fig. 9 and Fig. 10, that the pressure conditions within the nozzle remained stable and practically constant with such variations from the proper box pressure for each nozzle. Also, by applying the corrections called for in Par. 26 it is found that these values reduce to the same values as those obtained in lines 1 and 2, showing that the velocity and efficiencies of the jets as they reached the muzzles were not affected by the changes in box pressure.

18 The acceptance of the uncorrected values would therefore imply an assumption that in nozzle No. 14, with an initial pressure of 145 lb. and a terminal pressure of 0.929 lb., the jet attained a velocity of 3698 ft. per sec. in the nozzle, and that after leaving the nozzle its velocity jumped to 3843 ft. per sec., and that in nozzle No. 11, with

an initial pressure of 145 lb. and a terminal pressure of 1.682 lb., the velocity of the jet after leaving the nozzle dropped from 3796 ft. to 3561 ft. per sec.

19 The efficiencies calculated from the apparent reactions, if accepted in this form, would show that No. 14 is better than No. 11, not only for its own proper terminal pressures, but for the terminal pressures found in the muzzle of No. 11 as well. It may be that such is the case; but there is considerable probability of arriving at erroneous conclusions if it is assumed arbitrarily, without having first been proved by very careful experiments which are not in any manner dependent upon the assumption for their accuracy. There certainly is no basis for making such an assumption from these data as it has no bearing whatever upon the subject.

20 Previous to the time when this series of tests was begun, there had been considerable investigation of nozzles with cone angles up to 12 deg.; but the action of steam in nozzles of greater cone angle had not received the same degree of attention. It was therefore decided to use nozzles with divergence angles of from 9 to 20 deg., it being then thought that this upper limit might be beyond the value for highest efficiency.

21 Another set of nozzles tested contained one with a cone angle of 24 deg. 30 min., which seemed to show an equal efficiency with those of smaller angle. This set was made of babbitt metal, was not perfectly smooth and was somewhat worn with long-continued use, so that the results could not be thoroughly checked.

22 With the steam conditions given and the ratio of muzzle to throat area determined therefrom, the only point left for the designer is the general contour of the nozzle, including the shape of cross section, length and angle or angles of divergence. The two sets of nozzles shown in Fig. 6 and Fig. 7 were designed with this in mind, each set having a common ratio of areas; those of Fig. 7 differing among themselves only in length and consequent angle of divergence, or vice versa, and those of Fig. 6 differing only in elements of general contour, not including length.

23 Professor Moyer's statement that "nozzles of different lengths, but with the same taper or angle of divergence, should be compared," is not understood, unless he means to suggest that the whole field of different steam expansion ratios should have been investigated. This was not permitted because of limitations of time and other circumstances familiar to most investigators. Such an investigation would not serve to determine the proper length for a given steam expan-

sion ratio, because the different nozzles would not be suited to the same steam conditions; but it would give the efficiencies for one angle of divergence with all the pressure ratios to which the various nozzles were adapted.

24 Each set contained one search-tube nozzle for use in determining experimentally the terminal pressure in the muzzle, to be applied in reaction tests on the rest of the nozzles in that set. The efficiencies of these nozzles, No. 9 and No. 13, as calculated by the search-tube method, are shown in Table 5; but they are not worthy of consideration except as an example of the inaccuracies almost certain to be involved in this method. The high efficiency given for nozzle No. 13 is not due to greater precision in the experiments, as Mr. Knease suggests, but rather to the great error in the search-tube method of calculation, caused by a very small error in determining the muzzle pressure. In Table 6 it is pointed out that a "+ error" of only 0.1 lb. per sq. in. in determining the terminal pressure would cause a "− error" of from 5.4 to 14 per cent in the "search tube computed" efficiency of No. 9 and No 13.

25 These "search-tube computed" efficiencies are evidently responsible for Mr. Moyer's statement that efficiencies were here found as high as 97 per cent. Values obtained from reaction tests are lower, and it is upon these that the conclusions stated in Par. 49 are based.

26 No. 9 ("search-tube" nozzle) was made with a small angle of divergence, to be doubly sure that the steam should not leave the walls before reaching the muzzle.

27 Both the length and the ratio of areas in nozzle No. 10 were made to correspond as nearly as possible with those in nozzle No. 9 so that the terminal pressure found in the muzzle of No. 9 might be applied to reaction tests upon the former with the least possible error.

28 No. 11 and No. 12 were made shorter and with a greater cone angle but with the same sectional areas, in order to find out what difference, if any, this would make in efficiency.

29 No. 18 was finished rough for comparison with No. 11, upon which the greater number of tests had been made.

30 No 14 was used to determine the efficiency with a smaller expansion ratio.

31 No. 13 ("search-tube" nozzle) was made to correspond as nearly as possible with No. 14, so that the terminal pressure as determined in the former might be applied in reaction tests with the latter.

32 No. 15 and No. 16 were used to determine the effect of these very considerable variations in contour.

33 Other forms, such as shorter nozzles or those designed for uniform acceleration and upon other theories, may and probably do give just as good efficiency as those herein described. It seems doubtful, however, in view of the uniform results obtained with nozzles of such different contour as those covered by these experiments, whether it would be advantageous to use any form especially difficult to manufacture, unless it be for the purpose of controlling the shape of the jet as it strikes the moving blades of the turbine. This is very important, as it has a great effect upon the efficiency of action in the blades.

34 It is to be regretted, as stated in Par. 19, that we were unable to procure a calorimeter of sufficient accuracy for our purpose, but such great care was taken to maintain uniform conditions in the boiler room, and these conditions gave such repeated indications of the dryness of the steam at the nozzle entrance, that the probable error introduced is not serious.

35 As stated in Par. 14, the steam left the boiler under a pressure not varying more than 2 lb. from 155 lb. gage, and with about 50 deg. fahr., superheat. Steam was throttled to the required initial pressure just before entering the flexible pipe, with the result that the thermometer inserted at the nozzle entrance showed about 4 deg. superheat with 700-lb. flow per hr. and sometimes a trace of superheat with 500 lb. per hr. It is probably fair to assume from this that the steam was dry when used with 145-lb. pressure at the entrance to the nozzle, and that (in view of the greater throttling which tends to offset the increased unit radiation from the pipes) there was always less than 2 per cent of moisture present even with pressures as low as 100 lb. abs.

36 It may be stated in conclusion that a proper method of determining the net effect of under and over-expansion in the nozzle would be as follows:

First: Make a set of nozzles of the same cone angle and finish with throats identical, and with muzzles of different areas.

Second: Determine accurately the proper terminal pressure and the true efficiency of each nozzle, by the method herein described, using a reaction apparatus in which static and moving friction has been eliminated.

Third: Find the push upon a set of turbine blades, using each nozzle discharging into its own proper terminal pressure and into the pressures which are proper for each of the other nozzles of the set.

Fourth: A comparison of the push exerted under these conditions, bearing in mind the "true efficiency" of each jet within the nozzles, will show the net effect of under and over-expansion.

GAS POWER SECTION

THE WORK AND POSSIBILITIES OF THE GAS POWER SECTION[1]

By Fred R. Low, Assoc. Mem. Am. Soc. M. E.
Chairman for 1909

The work of the Section for the second year of its organized existence has been largely formative. The art, to develop and to chronicle the development of which is our avowed purpose, is so recent even in its beginnings, so new in weighty accomplishment, that it is possible for an organization with our facilities to gather and put upon permanent record the main facts of its history and the precedents and data evolved in its development. Our endeavor should be to do this in such a way that another generation will have no regret based upon the failure of ours to make a full and intelligent use of its opportunities.

The Standardization Committee has presented a preliminary report dealing with the significance of various terms used in the art. While nothing that we can do or say will endow any of these terms or quantities with an arbitrary measure or value, your treatment and disposition of the report will go far toward determining the future usage upon which legal and other interpretations will be based.

The Committee on Literature is organizing so as to provide for the systematic reading of current gas power literature, and the filing of index and reference cards with the librarian so that future searchers may find available information grouped for ready reference, and the information itself either in the files or elsewhere in the library. This is not retroactive, however, and some steps should be taken, while present but perishable information is available, to put upon record the history of the art, to make up its complete bibliography, a roster of its personnel and a chronological statement of its achievements; to

[1]Address of the retiring Chairman at the annual meeting.

write the subject of gas power down to date as Professor Dalby has written that of heat transmission.

The Installation and Plant Operations Committees have been occupied in perfecting systems, and the forms submitted for your consideration are parts of such systems, which are thought to coördinate with and to supplement each other and to fulfil all the purposes of the Section. The work of collecting information along these lines will be vigorously prosecuted during the coming year, and any suggestions which will improve the efficiency or practicability of the system will be of especial value at the outset of the work. In addition to these records of regular operation some effort should be made to obtain information as to operating difficulties overcome, and truths as to the behavior of a gas power plant in the hands of the user.

A number of laboratories are available for research work, and the Section is asked to suggest lines of experimentation. A large number of suggestions boil down to 42 determinations which it is desirable to make upon fuels; 8 questions regarding test methods, the determination of which is a matter of debate rather than of experimentation; 20 questions relating to producer practice; 5 to the effects of various factors on engine capacity and efficiency; 11 as to the effect of various elements of design; 6 upon ignition; 4 upon regulation; 3 upon carbureters; 6 upon the heat of the exhaust; 11 upon jacket water; 7 upon operative questions; 16 upon meters and analysis apparatus; 5 on the indicator; and 1 upon fire risk. Not all of these require physical experimentation for their determination, but the Section is fortunate in having received offers of coöperation from several of the foremost interested professional observers and investigators with well-equipped laboratories and skilled assistants at their command, and their thought and work will be invaluable in settling aright these perplexing questions pertaining to a new industry.

The results of the Meetings Committee's work are before you in the papers which have been presented at this and the other meetings of the year

The membership of the Society has increased during the year from 247 to 378, a gain of over 50 per cent.

The development of the past year has been steady, along lines already laid down at its commencement, rather than productive of new lines of thought or endeavor. I do not know that the record of the past has been surpassed either in magnitude of unit produced or in efficiency of performance. There has been some difficulty in

the production of large cylinders which would maintain their integrity under the extreme conditions of pressure and temperature which obtain when the entire process of conversion from the potential energy of the fuel to the energy of a revolving loaded shaft is conducted within the cylinder itself; and a metal which can be cast, and which has the strength to withstand the pressure in thicknesses which will allow the walls to be effectually jacketed, is a desideratum. Cast steel has gone far toward solving the problem. An alternative is a modification of design which shall permit the use of wrought metals.

Mr. E. T. Adams said early in the year that we were nearer a 10,000-h.p. unit, looking forward, than to a 5000-h.p. unit, looking backward. He has designed a station of 100,000-kw. capacity, which with 5000-kw. units will take no more space than a station of equal capacity with 14,000-kw. turbines, and we hope to have the particulars of the design for an early meeting.

The gas plant has been handicapped by the excessive first cost natural to a period of evolution and rapid development, but with standardization of design there will be a material decrease of cost. Present estimates would indicate a relation of first cost as between steam and gas power plants of about 100 to 130. The use of high piston speeds has done much to decrease the cost of the gas engine per unit of capacity, speeds of 1000 ft. per min. being not uncommon.

In Northern latitudes, where heating is an important factor, or in factories where large amounts of heat are used in manufacturing processes, the internal combustion engine is at a disadvantge because its efficiency is surpassed by that of the steam engine, when the latter is credited with its rejected heat available for such uses. The rejected heat of the gas engine, less than that of the steam engine by reason of its greater efficiency, is still some 75 per cent of that supplied to it. A large amount of this heat comes out in the jacket water at a temperature of about 140 to 180 deg.; the rest in the exhaust gases at a temperature of upwards of 1000 deg. A practicable method of applying this heat to useful purposes will greatly increase the field of the internal-combustion engine.

A number of engineers are at work upon the problem. One manufacturer passes such gases through conduits beneath the cement floor of his shop, maintaining the room at a comfortable temperature. Another inventor uses the exhaust gases to make steam from the already heated jacket water, supplementing them when necessary by burning gases from the producer beneath the

boiler. He labors under the disadvantage that the returns from the heating and process systems are not cool enough to go into the jacket and make the process a closed heat circuit.

The year has witnessed continued and new attempts at a gas turbine, with no results about which we can talk in detail. Mr. Hans Holzworth, one of whose steam turbines was exhibited at the St. Louis exposition, has exhibited a small gas turbine which ran so satisfactorily that he had no trouble in obtaining capital for the building of a 1000-h.p. unit, upon which he is now engaged at Berlin. Mr. W. A. Warman, one of our New York members, is obtaining some very interesting results in his efforts to construct a Hero turbine, Avery engine or Barker's mill, operated by gasolene.

The difficulty in the gas turbine is, of course, to find materials which can deal at the same time with pressures and temperatures both high. In view of the remarkable results obtained by the addition of low-pressure steam turbines to reciprocating engines, the conception of a gas turbine in series with a reciprocating gas engine naturally arises. The terminal pressure and temperature in a gas engine are high. There is considerable energy to be had by expanding the gas to temperatures attainable even under atmospheric pressures. At the same time, these gases are not so hot when they come from the engine that they cannot be readily worked in nozzles of easily procurable material. It would be interesting to see this adaptation worked out, at least on paper.

Notwithstanding the attractiveness of the two-stroke cycle, the smaller weight of engine required, etc., no progress has been made during the past year except upon engines of the smaller sizes, and we appear to be no nearer to the wider use of the two-cycle engine in large sizes than we were two years ago.

The movement toward the better use of by-product gases goes on. All the large iron and steel works use their blast-furnace gases in gas-driven blowing engines, pumps and electric generators, and coke manufacturers are putting in by-product ovens. It is said that German interests will erect a by-product plant near South Bethlehem which involves an investment of some $4,000,000 to furnish coke to the Bethlehem Steel Company, and which will have available some 24,000,000 cu. ft. of gas per day, of a thermal value of 400 B.t.u. At 10,000 B.t.u. per h.p.-hr. this amounts to 40,000 h.p. continuously.

Efforts continue toward a producer which will satisfactorily and continuously handle the more abundant and cheaper bituminous coals without expensive auxiliary cleaning apparatus and if reported

performances hold good, the year may be credited with notable progress in this direction.

Increasing interest is being taken in the use of substitutes for coal and oil. Numerous peat bogs are being worked and both peat and lignite are successfully used in producers. This is especially true of Western lignite. Occasional references are made to the possibilities of using town waste in the same way, but we have not learned of any notable progress in this direction during the year, and it is still a question whether the vast carbonaceous rejecta of our large cities can best be made to contribute to our fund of available energy by way of the producer or of the still.

The United States Geological Survey has just issued a bulletin, bringing the question of alcohol as fuel down to date. Burned in engines especially constructed for it, Messrs. Strong and Fernald, authors of the bulletin, say that a gallon of alcohol will develop as much power as a gallon of gasolene, notwithstanding it has but 71,900 heat units per gallon, as against 115,800 for the gasolene. The present price of denatured alcohol is 50 cents per gallon in five and ten-gallon lots, more than twice that of gasolene; but untrammeled by an internal revenue tax it would doubtless be a serious competitor of the latter fuel.

The usefulness of the gas engine in marine work was considered by Mr. Straub in his paper presented to the Section at the Washington meeting. Rumors persist to the effect that a sizable war vessel is being built in Great Britain, to be propelled by internal combustion-motors, and we understand that a contract has been awarded for a 1000-h.p. outfit for one of our own lake steamers. The successful application of gas engines to the propulsion of canal boats in Germany is well known.

REPORT OF GAS POWER RESEARCH COMMITTEE

A few months ago the Executive Committee of the Gas Power Section, recognizing the importance of a well-considered plan for the solution of the problems developed by the increasing use of gas power, appointed a Research Committee consisting of Prof. Robert H. Fernald, Prof. L. P. Breckenridge, Prof. Rolla C. Carpenter, Dr. Chas. E. Lucke, Prof. W. D. Ennis, Prof. W. T. Magruder, Prof. Harry N. Davis, Prof. Lionel S. Marks, Prof. David C. Gallup and Prof. W. H. Kavanaugh, with instructions to advise as to the proper lines of investigation to be conducted.

This committee, with the secretary of the Section as secretary, has prepared a list of the special problems in connection with the use of gas power, the solutions of which are urgently needed. It has been suggested that the well equipped engineering laboratories of colleges and technical institutions would be glad to coöperate in this work, and it is hoped that many of these problems will be taken up by laboratories and investigators and the results made public through The Journal of the Society.

A LIST OF PROBLEMS, THE SOLUTION OF WHICH IS DESIRED

A Fuels:

1 Compile from reliable sources comprehensive data concerning the coals of the U. S. which are worthy of consideration for use in gas producers .... L. P. B.

2 Use in the engine of producer gas direct from the generator with its full charge of tar .... R. H. F.

3 Use of bituminous coals and other tarry fuels in suction gas producers. R. H. F.

4 Use of briquetted lignite in producer. (Some work has been done at the Fuel-Testing Plant, Pittsburg.) .... W. H. K.

5 Sage brush, wood, in the producer .... R. H. F.

6 Use of peat in gas producers and methods of preparing it for use. R. H. F., W. H. K.

7 Use of briquetted peat in producer........ W. H. K.

8 Investigation of the rate (thoroughness) of dissociation of CO_2 in the producer at various temperatures .... W. D. E.

9 Ultimate analysis of ash in producer gas plants. (Also melting point of ash (clinkering) .... R. H. F., W. D. E.

10 Investigation of the temperatures prevailing in fuel beds of gas producers in conjunction with chemical investigations, R. H. F., L. S. M.

11 Ratio of air to fuel for best efficiency and comparison with theory. W. T. M., W. D. E.

12 Investigation of the effect on economic performances of varying the ratio of combustion.
 (*a*) In different types of producers with same fuel.
 (*b*) In same producer with varying sizes of fuel.
 (*c*) In same producer with varying mixture of fuel.
 (*d*) In same producer with coal mixed with limestone when the ash content of the coal is high.......................... L. P. B.

13 Effect of depth of fuel bed in gas producer work............ R. H. F.

14 Effect of sizing coal on producer efficiency............... R. H. F.

15 Determination of the effect of preheating the air in gas producers. R. H. F.

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17 Quantity of steam required per pound of fuel in producer gas plants. R. H. F.

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3 Establishment of a standard of efficiency for producers similar to the Rankin cycle for engines, based on pure carbon with (*a*) air only, and (*b*) an assumed percentage of steam..................W. D. E.

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TESTING SUCTION GAS PRODUCERS

By C. M. Garland and A. P. Kratz, Published in The Journal for December

ABSTRACT OF PAPER

The paper describes a method of testing the suction gas producer which is independent of the engine. The engine is blanked off from the producer and a Schutte & Koerting steam ejector is inserted, which draws the gases from the producer and delivers them to a scrubber in which the steam used by the ejector is condensed. The gases then pass to a Westinghouse meter where the volume is determined.

A large part of the paper is devoted to the forms used in the computation and presentation of the results on gas-producer tests. Three forms are given, Nos. 1, 2 and 3. Form No. 1 is used only for the final presentation of the results of the tests; form No. 2 includes the results of all computations for convenience in computing; and form No. 3 contains the derivation and the discussion on the derivation of the formulæ used. The formulæ appearing in this form are arranged in the order of computation and the item numbers refer to the items of form No. 2.

The results of one test are included in the paper together with a graphical log illustrating the conditions during this test.

DISCUSSION

Prof. R. H. Fernald. In connection with the Government investigations, the feeling has prevailed that ever since the beginning of the work in 1904, gas producers could be tested on practically the same basis as steam boilers, i. e., without necessarily operating an engine in connection with the test. This would mean discharging the gas into the air in a manner similar to the discharge of steam in boiler test practice. This method of procedure has not been adopted at the Government testing station because so much prejudice has existed against the gas producer and gas engine. It has therefore been necessary that the gas generated at the testing station be utilized in an engine in order to avoid any discussion relating to the uncertainty of such operation. This has been particularly necessary owing to the large variety of fuels that have been handled and the variation

in the quality of gas produced. It is true, however, that from the producer standpoint alone the engine is not essential, and the method suggested by Mr. Garland is ingenious and reasonably convenient.

2 There are a few points in connection with this paper upon which further information is desirable. In Par. 5 it is stated that the weight of steam was measured by passing the jet through a calibrated orifice in a thin plate. Methods of determining the quantity of steam used by gas producers seem to be varied and the results obtained somewhat uncertain. I believe it would be interesting to know the details of the method employed by Mr. Garland. In the testing station at St. Louis the steam used by the pressure producer was determined by means of a calibrated orifice, but the fluctuations in pressure were such that the readings obtained were not regarded as absolutely reliable. During tests covering a period of approximately two years the steam used varied from 0.28 lb. per lb. of coal fired to 1.13 lb. of steam per lb. of coal fired. The average for twenty consecutive tests showed 0.69 lb. of steam per lb. of coal fired. It should be borne in mind that the fuels used for the different tests were quite different in composition and that the amount of steam required by the different fuels may have varied considerably; but in spite of this fact the feeling which prevailed about the plant was that the method of determining steam by means of calibrated orifices was not entirely satisfactory unless the pressure of the steam passing into the producer, and the percentage of moisture in the steam, could be kept constant during the test.

3 At the Norfolk station, however, the steam required by the producer was supplied by an auxiliary boiler, so that all water passing into this boiler could be positively measured. Although the coals used for the six tests reported below were practically the same in composition, yet the records show the steam consumption per pound of coal fired to be decidedly variable, as follows:

(1) 1.12 lb. per lb. of coal fired	(4) 0.82 lb. per lb. of coal fired
(2) 1.14 " " " " " "	(5) 0.77 " " " " " "
(3) 1.04 " " " " " "	(6) 0.69 " " " " " "

This wide variation shown for these six tests is due entirely to the methods of operation, and not to uncertainties in measurement, as might at first be inferred. There is need of systematic and careful investigations relating to this question of steam per pound of fuel. At the Pittsburg station the method of determining the amount of steam used in the vaporizer is by means of a water tank calibrated in pounds, thus insuring accurate measurement.

4 In Par. 6 is presented the general method of determining the amount of fuel used. One phrase attracts especial attention: "at the end of the test the fuel bed being brought to as near the starting condition as possible." In boiler practice where the quantity of fuel on the grate at any one time is relatively small, it is undoubtedly possible, within a reasonable percentage of error, to determine the condition of the fuel bed and to make this condition practically the same at the beginning and close of an eight or ten-hour test.

5 However, the situation is totally different in gas-producer practice in which the initial fuel supply and the amount of fuel on the grate at any given time is large compared with the amount required by the plant during a run of a few hours only. Even though the conditions at the close of a producer test be made to duplicate those at the beginning, there is still considerable difficulty in determining the exact fuel consumption, owing to the lack of accuracy in determining the true thickness of the fuel bed. In a producer of 250 h.p. rating it is not uncommon to make an error of from four to six inches in the true depth of the fuel bed. In a producer of this size, this will cause an error of about 800 lb. of coal, or about 400 lb. of coke, according to the condition of the fuel bed at the time. It is imperative, therefore, that the tests of producer plants be continued to such length that these errors in measurement will be but a small percentage of the total fuel consumed.

6 Mr. Garland states that it was endeavored to make the tests of such duration as to bring the probable error of filling down to about two or three per cent. It will be of interest to have explained in further detail the method of procedure used in determining the exact amount of fuel consumed. With a 250-h.p. plant in which the fuel consumption for a period of 8 hr. amounts to only 1800 lb. approximately, the error due to inaccurate measurement of the depth of bed and variations in fuel bed thickness may be as great as 1150 lb. The percentage of possible error in calculating fuel consumption for short periods is obviously great. With a period of 24 hr. and a fuel consumption of about 5400 lb., the percentage of possible error, although much less, is still over 20 per cent.

7 In the producer tested the effective fuel bed volume was approximately 4 cu. ft., which is equivalent roughly to 250 lb. of anthracite pea coal. It is probable that a large percentage of the gas value of this coal may be given off without materially decreasing the fuel volume, under certain conditions of fuel bed. In a run in which the fuel consumption for this producer amounts to only 800 lb. with an

initial bed of 250 lb., it is a question whether the percentage of error in fuel bed estimates may not amount to 10 or 12 per cent instead of 2 or 3 per cent.

8 In a recent paper on this subject published by the United States Geological Survey, the following conclusions were presented:

a Throughout a test the fuel bed should be maintained in uniform condition, with regard both to character of the fire and thickness of the bed.

b Failing in this, special care should be exercised to see that the fuel bed is in the same condition and of the same thickness at the close of the complete test or at the end of a test period, as at the beginning.

c A test should never be started when the producer has been standing idle for some time with banked fires, as the fuel bed will not be in the average condition under which it will be required to work during the test.

d If, as the appointed hour for closing the test approaches, the fuel bed is not in the proper condition, the time of ending the test should be postponed until the bed naturally assumes the proper thickness and character. No forcing of conditions should be allowed simply to bring the test to an end at a previously determined hour.

9 In Par. 12 it is suggested that the volume of gas may be computed from the analyses of the gas and coal and the statement is made that this "may be relied upon within 5 per cent, provided the sampling is accurate." This last clause "providing the sampling is accurate" seems to contain the essential point. Time does not permit a lengthy discussion of this important subject, but too much emphasis cannot be placed upon the fact that proper sampling is difficult to accomplish.

10 Reference to the packing of the ash in the fuel bed suggests another point which must be very carefully considered in making fuel bed measurements, viz., the swelling of any coals due to the application of heat. Frequently in our government tests, the measurements of the fuel bed have caused very misleading impressions due to the fact that the fuel had swollen materially during the operation of the plant.

11 In Form 1 a number of items appear under a heading "Quantity of Air." Although it is quite possible to determine small quantities of air with some degree of reliability, yet methods for making such measurements of large quantities appear to be entirely lacking.

Further details of the methods pursued in this test will, I believe, prove of interest.

12 In items 128 and 128*b*, are presented the producer efficiencies based on dry coal and combustible. It is not apparent why there should be a difference of 4 per cent in the efficiencies shown.

G. M. S. Tait. The usual method of testing a plant for such a short period would be to operate the producer for two or threedays beforehand so as to bring the fuel bed to an average working condition, that is, with an average amount of carbon in proportion to ash. Then a comparatively short run, provided great care was taken as to the fuel depth, would give fairly reliable figures. Otherwise, when drawing on a fresh fire and making a run of only twelve hours, it would be necessary to pull the entire fuel bed at the end of the run and analyze the contents for carbon and ash, in order that any sort of accuracy might be obtained.

2 In one of the author's tests, instead of 34 lb. of coal per sq. ft. of grate area, 8 to 10 lb. would be a normal figure, as 34 lb. of coal per sq. ft. is entirely impracticable for anything but a very short run on American fuels. In this test a large part of the coal originally in the producer was apparently burned to ash, and its consumption was completely left out of the test, causing very erroneous results.

3 Attention is called to the fact that the ash content in the ashpit is practically much less than the ash content of the fuel, as shown by analysis. The balance of the ash is undoubtedly in the fuel bedand its presence there entirely upsets the basis of calculation for this paper. It is safe to say that a two days' run would have given a reversal of the first day's figures.

H. H. Suplee. I would like to speak of the unreliability of an orifice as a means of measuring. Only this morning a member called my attention to the discharge of steam from a boiler in which the orifice and all conditions surrounding it were identical in several tests. The amount of steam generated was measured by carefully weighing the water, double-checking it in tanks, and yet there was a variation of ten to fifteen per cent in the results, the steam pressure and the temperature being kept as uniform as possible. This fact casts a doubt on the orifice as a means of determining flow.

L. B. Lent. The figures given show that the draft through the producer was practically 1½ in., and yet 38.8 lb. of dry coal was

burned per sq. ft. of grate area. Still, with this consumption the producer efficiency seems to be very good. My impression is that this is a remarkable rate of consumption in producers of large type; and I would like to know if this is the common practice in smaller sizes of producers.

H. F. Smith. Regarding the conditions of the fuel already discussed it seems to me that the author has presented all the necessary evidence to show that the conditions in the fuel bed were not the same at the end as at the beginning of the test.

2 In the graphical log in Fig. 3, it will be noticed that the temperature of the gas leaving the producer at the beginning of the run was 400 deg. fahr., and at the end of the run something over 1300 deg. fahr. The rates of gas production and fuel consumption were practically uniform. It is evident that there was some variation in conditions, otherwise this difference in temperature would not have occurred.

W. B. Chapman. Perhaps I can answer Mr. Lent's question in regard to the quantity of coal gasified in producers. Producers for furnace work are usually rated at 10 lb. per sq. ft. of internal diameter on Pennsylvania coal, but only 7 lb. per sq. ft. on Illinois coal. The best record I have seen for *hand-operated* bituminous coal producers was 16 lb. per sq. ft. Mechanically agitated producers gasify from 15 lb. to 30 lb. per sq. ft.

2 The question of the amount of anthracite coal that can be gasified is very interesting. Engineers from abroad say that two or three times as much can be gasified as is the custom in this country. Every gas producer manufacturer in this country having a foreign engineer in charge has designed his first producer very much too small. The more experienced manufacturers do not rate their producers at more than 10 lb. per sq. ft.

3 It is strange that we cannot get the results said to be obtained in foreign countries. The difference must be in the coal.

Prof. R. H. Fernald. In reference to the rate of burning per square foot of grate area, I desire to call attention to the high figures shown by Mr. Garland. These figures seem to be very unusual for this type of producer even under the test conditions described. The highest rate with which I am familiar in commercial operation is that found in the case of a large installation using lignite as fuel. This

plant shows a daily rate of 33 lb. per sq. ft. of fuel bed area per hour during 16 hours each day and 48 lb. during the remaining 8 hours. In this installation the producers are of the down-draft type, but even under these conditions this rate is, I believe, exceptional.

2 In reference to Mr. Chapman's remarks about the manufacturers abroad, I would say that apparently all of them stipulate the type of coal that shall be used in their producer. They specify that the coal must be of such and such a grade, non-caking and with only such and such a percentage of ash and tar. As nearly as I was able to ascertain, practically every manufacturer abroad has reached the conclusion that it is wise to designate definitely the coal to be used.

3 In one suction producer in Germany, operating on bituminous coal, I found that the successful manipulation of the plant was due to the fact that three kinds of coal, mixed in the proper proportions, were being used. In other words, this type of producer using bituminous coal as fuel was entirely feasible in the home plant of the manufacturer, but it would hardly prove a saleable article in this country, as it would be almost impossible to guarantee the three required grades of coal at all times. It would also be out of the question to secure operators at a reasonable compensation who would give the plant the required attention.

E. N. Trump. The rate of combustion in producers using anthracite coal depends very much upon the size of the coal. Seven tons per 24 hours, with a producer 7 ft. in diameter, is about the maximum for No. 1 buckwheat coal. This equals 15 lb. per sq. ft. of grate surface per hour.

2 Burning Western coals in producers, especially Hocking Valley coal, a high rate of combustion is obtained. I have operated producers continuously for a considerable period at the rate of 42 lb. per sq. ft. of grate surface. This is with a large percentage of steam in the air, also with mechanical ash extraction, the fuel bed being thus kept well agitated.

2 Venturi meters give very accurate results in the measurement of both gas and steam, much more accurate than the simple orifice.

The Authors. It will be well to emphasize the fact that the producer under discussion was designed and intended for intermittent service only; that is, it is not suitable for runs of greater than 12 to 18 hours duration. This is due to the small size of the producer, and

the absence of charging bell, water-sealed ashpit and mechanical means for agitating the fuel bed.

2 Owing to the small size of the producer and the absence of means for thoroughly cleaning the fuel bed from time to time, as above noted, the accumulation of ash toward the end of 12 or 15 hours of continuous operation is so great as to necessitate such thorough cleaning as seriously to lower the heating value of the gas.

3 From the foregoing it will be evident that our test corresponds to the conditions under which the producer is normally operated. Owing to the thorough cleaning of the fires before starting the test, and the removal of the ash from the grate, a large quantity of green fuel is brought into the path of the outgoing gases, resulting in their being cooled. At this time, the temperature of the fuel bed is also lower, as indicated by the analysis of the gases over the first two hours of the test. The heating value of the gas is not lowered, for two reasons: first, the descent of the green fuel into the path of the gases results in the distillation of the CH_4 and other heavy hydrocarbons; secondly, an increase in the percentage of hydrogen results from the lower temperature of the fuel bed.

4 At the close of the test the fuel bed was evidently at a higher temperature than at the start. This resulted in increasing the unaccounted-for loss in the heat balance, but its extent (estimated from the results of a number of tests) is about one per cent for the present test. This, it is believed, explains the condition pointed out by Mr. Smith.

5 Professor Fernald and Mr. Tait call attention to the probable inaccuracy in determining the weight of coal fired on the test. We have recognized this source of error, and in Form 2 have included such items as give proof of the accuracy of the work through the stoichiometric relations. As the full import of these items has evidently not been realized, we will amplify them.

6 First, to determine approximately the purely mechanical error in estimating the weight of coal fired during the present tests, the producer was filled four separate times, and the weight of coal required was noted in each case. The average of the four weights was taken as the mean or true weight of coal required to fill the producer. The results are given in Table 1, herewith. It will be seen from this table that the maximum variation from the mean is 8.75 lb., or 1.7 per cent. This in the test under consideration represents an error of probably 1.1 per cent.

7 Mr. Tait seems to think that the presence of the ash in the fuel bed "upsets the basis of calculation for this paper." The total weight of ash in the dry coal is 776.5 lb.; 13.17 per cent = 102 lb., of which 52 lb. was taken out in the ash and refuse, leaving 50 lb. remaining in the fuel bed. This would seem to indicate an error of 6.3 per cent, due to failure to remove this ash. Since the ash is soft and fine it would pack into the interstices between the coals so that its volume would by no means displace the same volume of coal. If it displaced one-half its volume of coal it would cause an error of slightly over 3 per cent. It is probable that its presence caused even less error than this. In order to bring out the different errors we will analyze the conditions existing on the test.

TABLE 1 WEIGHT OF GREEN COAL REQUIRED TO FILL THE PRODUCER

Trial Number	Weight Lbs.	Variation from Average Weight	Per Cent Variation
1	669.25	−8.75	1.70
2	676.25	−1.75	0.26
3	683.25	+5.25	0.77
4	683.25	+5.25	0.77
Total	2712.00		
Average	678.00		

8 It is probable that the composition of the producer gas on leaving the scrubber, and at any two points in the cross section of the main, is the same. In order to eliminate such an uncertainty, however, we have taken the gas for our samples simultaneously from different points in the cross section of the main and at a point beyond the scrubber, by means of the sampling tube illustrated in the paper. These samples were taken continuously over the period of the test, both for analysis and for the calorimeter. The heating value of the gas, as computed from analysis, is 138.1 B.t.u. After corrections were made for the error in the meter, the error due to the vapor pressure of water, and the error due to radiation and conduction into the calorimeter, the heating value of the gas as determined by the Junker calorimeter was 137.3. Since the heating value as determined from two separate samples of gas, by two independent methods, and by two independent observers, checks within 1 per cent, it must be admitted that the sampling, the analysis and the heating value of the gas are probably correct within less than 1 per cent.

9 The volume of gas generated by the producer was measured by

a Westinghouse meter, guaranteed by the company to be accurate within 2 per cent. However, as a further precaution, the meter was carefully recalibrated and was found to be accurate within this limit. A calibration curve was plotted from the calibration, so that the error in determining the gas volume must have been within 2 per cent, and was doubtless even closer than this.

10 As shown by a number of tests on the present fuel, the coal was fairly uniform. A sample representing about 15 per cent of the coal fired was mixed and quartered until about eight or ten quarts remained. This was then ground, and again mixed and quartered until sufficient to fill a quart jar remained. The heating value from this sample as determined by the calorimeter was 13,040 B.t.u. per lb. The mean of eight determinations on this same fuel showed a heating value of 12,900 B.t.u. The probable error in the analysis and in sampling the fuel, judging from the heating value, is doubtless not greater than 1 or 2 per cent.

11 We have noted the volume of gas computed from the analysis of the coal and the analysis of the gases in Form 2, Item 126. This volume is 56,200 cu. ft. of standard gas, while the volume as actually measured by the meter, corrected for the vapor pressure of water, is 57,500, showing a discrepancy of about 2.3 per cent. The volume determined from computation was obtained from the formula of Item 126, Form 3. It is based on the fact that the weight of carbon in the coal fed to the producer must equal the weight of carbon appearing in the producer gas, plus the carbon lost in the ash, plus the carbon lost in soot and tar, plus the carbon lost by the absorption of CO_2 and CO by the scrubber water. The carbon lost in the ash is readily obtained, the carbon lost in the soot and tar is not over 1 per cent, while the carbon lost through the absorption of the gases by the scrubber water is also very small.

12 It may be well to compute the carbon in the gas and compare this with the carbon fed to the producer in the coal. We will compute the latter first. The total carbon in the coal is 0.7984 x 776.5 = 620 lb. The total carbon in the ash is 0.388 x 85 = 33 lb. The carbon that should appear in the gas is therefore 587 lb. The total weight of gas from Item 131, Form 2, is 3912 lb.

Carbon in CO_2 of gas	$= 0.0716 \times 12/44 \times 3912$	$= 76.4$
" " CO " "	$= 0.2925 \times 12/28 \times 3912$	$= 490.5$
" " CH_4 " "	$= 0.0112 \times 3/4 \times 3912$	$= 32.8$
		599.7

Thus 599.7 lb. is the total weight of carbon appearing in the gas as measured by the meter. $599.7 - 587 = 12.7$ lb. of carbon unaccounted for $= \frac{12.7 \times 100}{599.7} = 2.1$ per cent. As already stated, there may be an error of 1 per cent in the meter by which the above volume of gas was determined, the error being either positive or negative. There may have been 1 per cent of carbon lost in the soot and tar, but not more than this; there may also have been an error in the analysis of the coal amounting to $1\frac{1}{2}$ per cent. We estimate the principal errors in the test as follows:

	%
Error in filling the producer	-2.1
Gas analysis or heating value of gas	± 0.7
Volume by meter	± 1.5
Coal analysis and sampling of coal	± 1.5
Carbon lost in soot and tar	-1.0
Loss in sensible heat in the fuel bed due to the lower temperature at the start than at the close of the test	-1.0

The total error in the results of the test that would affect the cold-gas efficiency of the producer, if all the above errors are assumed as accumulative, equals .8. The probable error is 2.7.

13 There are three other errors that may affect the heat balance, namely, the error in measuring the temperature of the outgoing gases, the error in the determination of the specific heat of these gases, and the error in the amount of steam fed to the producer. The error in measuring the temperature of the gases may be 2 per cent; the error in determining the specific heat of the gases may be 6 per cent; the error in determining the steam fed to the producer may be 25 per cent. If these errors are accumulative, the first two represent a total error based on the heating value of the fuel of about 2 per cent, and the third of about 1 per cent. Therefore, if all errors are accumulative, the total error in the heat balance is about 6.8 per cent; as some of these errors will be positive and others negative, the probable error in the heat balance is about 3.5 per cent. As the heat balance shows an unaccounted-for loss of 4.4 per cent, about 1 per cent being radiation and conduction, the actual error in measuring the coal delivered to the producer on this test could not have exceeded 3 per cent. We have therefore been able to run tests of such duration as to reduce the probable error in filling the producer to 2 or 3 per cent. Furthermore we believe the results indicate that they are above the average in

accuracy for this kind of work, as we have seen very few tests on producers that would stand the above analysis.

14 As Professor Fernald and Mr. Suplee have pointed out, we have found the use of the thin plate orifice for the measurement of steam not altogether satisfactory. As the heat supplied in the steam on most of our tests is small, a large error is permissible in the measurement. Our aim has been to vary the pressure on the orifice so as to keep the hydrogen content of the gas practically constant. It might be well to state that the orifice was used only while we were obtaining a new vaporizer for the producer.

15 We have found no tendency in the anthracite coal to swell. We believe that this is a property of bituminous coal containing large quantities of moisture and of hydrocarbons.

16 As the quantity of air does not enter into the computation of the more important quantities, it was computed from the nitrogen in the producer gas. The formulae for this computation are given in Form 3.

17 The difference in the efficiency based on dry coal and the efficiency based on combustible, as noted by Professor Fernald, is due to the fact that we have used the word combustible as defined in Form 3, Item 54. This takes into account the grate efficiency. The result is that the efficiency based on combustible corresponds to the efficiency based on 100 per cent grate efficiency. It is used for the reason that it is often desirable to show relations between efficiency and other quantities that are independent of the grate efficiency.

18 The amount of coal burned per square foot of grate area is a very variable quantity and depends upon the size of the fuel, the kind of fuel, the nature of the ash, the amount of water supplied, the proportions of the producer, the operation and the length of run.

19 For intermittent work, such as the present producer is adapted for, and with coals containing an ash infusible at temperatures under 2300 deg. fahr., it is possible to operate at several times the capacity possible with coal containing a fusible ash which necessitates a low fuel bed temperature.

20 The rapidity and extent of the reaction of CO_2 on incandescent carbon depend upon the temperature and upon the catalytic action of the fuel. At a given temperature and an indefinite time of contact of gases with the incandescent carbon, a definite amount of CO_2 and CO will be formed. The lower the temperature the less the per cent of CO formed and the longer the time required for equilibrium, so that with low temperature in the fuel bed the time of contact of the

gases with the fuel must be greatly increased. The same is true for the reaction of water on incandescent carbon. Harries[1] passed water vapor over incandescent carbon at different temperatures and obtained the results given in Table 2. These results show the effect of temperature upon the water-gas reaction. Due to the low temperature, the CO_2 is high, the CO is low and the ratio of water decomposed to water supplied is small. The latter fact, in the case of the producer, results in lowering the efficiency, as the undecomposed water carries out a large quantity of heat.

21 The curves of Fig. 1, herewith, taken from Dr. Clements'[2] work on the rate of formation of CO in gas producers, illustrates the effect of the time of contact, expressed in terms of velocity in feet per second, upon the amount of CO formed in passing CO_2 over incandescent anthracite coal. At a temperature of 1100 deg. cent., and a time of contact corresponding to a velocity of 1 ft. per sec., 11 per cent of CO is formed. If the velocity is reduced to 0.1 ft. per sec., so that the time of contact is increased ten times, 70 per cent of CO is formed. If an indefinite time of contact is assumed, equilibrium is reached at

TABLE 2 EFFECT OF TEMPERATURE ON WATER-GAS REACTION

Temperature Deg. Cent.	H_2	CO	CO_2	H_2O
674	8.41	0.63	3.84	87.12
838	28.68	6.04	11.29	54.09
954	44.43	32.70	5.66	17.21
1125	50.73	48.34	0.6	0.303

this temperature with 90 per cent of CO formed. This illustrates why it is necessary to use a small rate of combustion per square foot of grate area, due to operating with coals requiring a low temperature for the prevention of clinker formation.

22 If in the example just cited the temperature had been 1300 deg. cent. in the fuel bed, 70 per cent of CO would have been formed at a velocity of 0.5 ft. per sec. The time of contact would have been reduced five times, so that the rate of combustion could have been increased almost five times without appreciably changing the composition of the gas or the depth of the fuel bed.

23 In the case of our tests with the Scranton pea coal, we have

[1] Habers, Thermo-dynamics of Technical Gas Reaction, p. 138.

[2] Bulletin No. 30, Engineering Experiment Station, University of Illinois.

been able to vary the coal per sq. ft. of grate area from about 10 lb. to 45 lb., without appreciably affecting the efficiency of the producer. At the higher rates of combustion, however, the producer requires much more attention. If it were not for the fusion of the ash, the weight of coal per square foot of grate area could be increased indefinitely by the use of a blast and a sufficiently deep fuel bed.

24 The term "coal per square foot of grate area," as used in producer practice, is not, we believe, a true basis of comparison for the operation of different producers, for the reason that the coal per

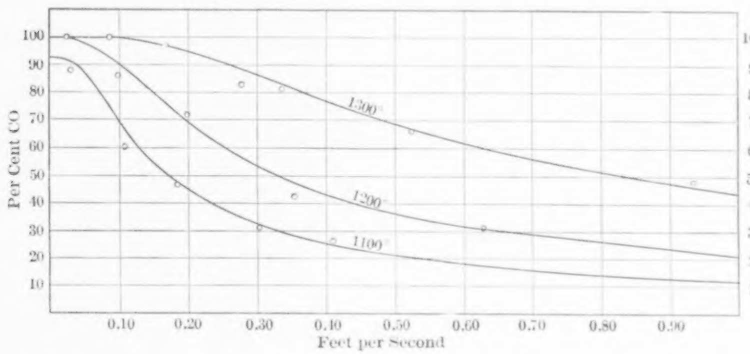

FIG. 1 VELOCITY OF GAS IN FEET PER SECOND, FUEL BED 1 FT. DEEP

square foot of grate area depends to a certain extent upon the depth of the fuel bed. For this reason, largely, we have used a term, "rate of descent of coal through the fuel bed," or "coal per cubic foot of fuel bed per hour," which appears under Items 70 and 71 in Form I.

BITUMINOUS GAS PRODUCERS

By J. R. Bibbins, Published in The Journal for December 1909

ABSTRACT OF PAPER

This paper attempts to throw some light on the results of the development of a comparatively new type of apparatus, the double zone bituminous gas producer.

Much time and money have been spent by the various manufacturers in the development of a tar-free gas producer and in some respects the obstacles have seemed insuperable. Every advance is therefore of interest and importance, and it has seemed worth while to report a long series of tests conducted by the builder to determine the net results under commercial conditions, whether good or bad. These tests are characterized by their unusual duration and absence of outside conditions affecting the results.

These results in general will speak for themselves and it is necessary simply to emphasize the fact that continuous operation has been secured with tar-free gas of reasonable heat value and producer efficiency and an over-all plant economy of about one pound of fair bituminous coal per brake horsepower (proportionate economies for poorer grades). More important still, the fact has been developed that the efficiency and general effectiveness of operation of the producer on low grade fuel, lignites, etc., is practically as high as with the higher grades. This places within the reach of the producer the enormous fuel deposits of the West and South, which are practically invaluable for steam work.

DISCUSSION

G. M. S. Tait. The results reported in this paper are entirely in accord with what we have found, namely, that the gas of the lesser British thermal units is much more satisfactory for engine practice. In other words, the efficiency of a gas of 90 B.t.u. is proportionately double that of a gas containing 600 B.t.u. per cu. ft., the gases in question being respectively blast-furnace gas and gasolene vapor.

2 I would like an expression of opinion as to the reason for this great discrepancy in efficiency between the two gases, my own opinion being that the excessive normal losses are due to the sudden high temperature developed in the gas of high B.t.u., which is greater than can be handled by normal piston speeds.

3 The tar washer used in this test appears to be a succession of water seals and I would like to know what would be the total frictional effect of these seals under normal conditions and on full load.

4 In all producers properly designed the thermal efficiency appears to remain constant between 20 per cent and 100 per cent load. I can confirm Mr. Bibbins' experience as to the action of this particular class of fuel and its desirability for producer work.

Prof. R. H. Fernald. Mr. Bibbins places as his first essential requirement "continuous operation 365 days per year," and states that any departure from this condition means reserve equipment. He also states that the condition for producer operation must parallel steam boiler practice.

2 It is undoubtedly true that a producer which will operate continuously 365 days a year would prove a splendid commercial proposition, but it seems to me that in the requirements outlined the conditions imposed are much higher than those of any steam boiler plant and are beyond practical requirements. Every plant of any size must necessarily have one or more reserve units, as no plant can operate continuously 24 hours a day 365 days a year. If the producer described by Mr. Bibbins can approach this operating condition, it will certainly revolutionize our present day power-plant practice. It would seem advisable, in the light of the present development of gas producers, to impose conditions which are less severe.

3 Relating to the adaptability of a single producer to all classes of fuel, it is well to bear in mind that the government testing station has practically demonstrated the fact that almost any variety and grade of our recognized fuels can be handled with more or less success in a given producer installation without change of details of design. It is questionable, however, whether such practice lends itself to the efficient use of a wide range of fuels. It is probable that better results can be obtained by utilizing a producer type to cover a certain range or variety of fuels and another plant of somewhat modified design for another range.

4 Mr. Bibbins refers to the excessive labor required by most producers. At the present time the labor requirements are excessive for the majority of the plants utilizing bituminous coal. This labor, however, even under bad conditions of operation, such as those involved when the fuel is one that clinkers badly, probably does not exceed that of the average steam installation, although the labor is of a somewhat different character. During the regular operating

period of the plant this labor may amount to very little; but at the close of a week, two weeks, or any length of operating period, in the commercial plants now in operation, cleaning may be an exceedingly dirty, hot and tedious operation. With the steam boiler plant the labor is more uniformly distributed. In spite of the more erratic and more violent labor required at times by the producer installation, the total cost for cleaning, ash removal, etc., is probably within the limits of the average steam installation.

5 Experience with a large variety of fuels leads one to question whether the treatment accorded one fuel in order to prevent clinkering will produce the same results with a fuel possessing totally different characteristics. The impression from the tests carried on at the Geological Survey testing station is that fuels varying greatly in composition and in characteristics require widely different treatment. This impression has been obtained from tests on a large variety of fuels, but the number of tests on each of the different fuels was not sufficiently large to warrant positive conclusions regarding this point. European practice, however, seems to confirm this opinion, as practically every producer manufacturer finds it imperative to specify coals of certain characteristics for use in his type of producer and does not guarantee the plant on fuels outside of this class.

6 In the discussion of the results the point is brought out that with Texas lignite the rate of combustion in this producer can be so increased as to permit the same rating of the producer as when operating on a high-grade fuel. Note is made of the fact that a charging rate of 27.2 lb. per sq. ft. per hr. was obtained with this lignite. An installation in Texas, which I visited a year ago, consisted at that time of three producer units of 1100 h.p. rating each, or a total of 3300 h.p.

7 Owing to the character and high percentage of the ash, together with the excessive demands upon the plant each unit was cleaned every third day, or, what amounts to the same thing, one unit was cut out of operation during a part of each 24-hr. day. It required eight hours to cut out the gas from a given unit, to clean thoroughly, rekindle fires and cut in the new gas. During each 24-hr. day, then, the full plant capacity, rated at 3300 producer h.p. was in operation 16 hr., while only 2200 producer h.p. were in operation the remaining 8 hours. During the entire 24-hr. period, however, according to the operating records, the engines were developing 2800 h.p. The operating records also showed that the fuel consumption per square foot of fuel bed area per hour amounted to 33 lb. during the 16-hr. period and 48 lb. during the 8-hr. period.

8 The statement is made that the economy of less than 1 lb. per b.h.p.-hr. is probably below previous results in bituminous producers. It is assumed that this statement is not intended to cover the tests at the government testing station, which has reported a number of instances in which the consumption varied between 0.8 lb. and 1 lb. per b.h.p.-hr.

9 Mr. Bibbins states that perhaps the most important result is tar-free gas. It is undoubtedly true that tar-free gas is eagerly sought in all cases in which the gas is to be used in engines. In my own mind, however, it is somewhat questionable whether tar-free gas, as reported in this paper, means that the gas from any and all fuels used in this plant would necessarily be free from tar. Experience with a producer of somewhat different design shows tar-free gas with the majority of fuels, but in the case of certain fuels the results are quite the reverse. If the producer under discussion can produce tar-free gas from any and all varieties of fuel, it is certainly a development in the right direction.

10 In the closing paragraph of Mr. Bibbins' paper the impression is conveyed that the steam boiler units of 2000 and 3000 h.p. are found not infrequently, and that producer units are small in com-

TABLE SHOWING CAPACITIES OF PRODUCER-GAS POWER PLANTS

	No. of plants	Horsepower				Per Cent of Total	
		Total	Average	Minimum	Maximum	No.	H. P.
Anthracite Coal:							
Over 500 h.p.	8	7,550	950	600	1500		
500 h.p. or less	407	40,550	100	15	500		
Total	415	48,100	116	15	1500	88	43
Bituminous Coal:							
Over 500 h.p.	20	49,000	2,450	750	6000		
500 h.p. or less	17	5,150	300	35	500		
Total	37	54,150	1,460	35	6000	8	49
Lignite:							
Over 500 h.p.	3	7,275	2430	525	3750		
500 h. p. or less	19	1,725	90	25	250		
Total	22	9,000	410	25	3750	4	8
All Plants	474	111,250	235	15	6000	100	100

parison with the usual boiler unit. In my opinion the condition at the present time is quite the reverse of this. In European practice it is not uncommon to find producer units of 1250 and 2500 h.p., and in the United States units of considerable size are in commercial operation, as shown by the accompanying summary of the producer-gas power plants operating in June 1909. There are undoubtedly over 500 plants in operation, as the list includes 474.

11 It is true that many of these larger plants are made up of several units, but an inspection of the original data shows the following single units of 500 h.p. or more:

H.P.	No.	H.P.	No.
500	4	1000	10
625	6	1500	1
750	3	2000	7

One single unit of 3,000 h.p. and one of 4,500 h. p. are reported, but these figures have not been verified.

12 It is interesting to observe that about 88 per cent of the total number of installations in the country are operating on anthracite coal (a few using charcoal or coke) and that bituminous coal and lignite are used in the remaining 12 per cent. It is not strange, therefore, that the majority of plants are at present made up of relatively small units, although the number of large units is rapidly increasing as bituminous plants are becoming more common. In point of size the bituminous plants at present average $12\frac{1}{2}$ times the size of the anthracite plants. Of the total horsepower approximately 57 per cent is derived from bituminous coal and lignite, and 43 per cent from anthracite coal, charcoal and coke.

13 Although in large central stations there are many operating advantages in relatively small units, yet it is believed that in the near future central station development will demand equipment of much larger capacity. A consideration of the fuel resources of the country indicates that in order to keep the price of power developed from fuel down to a consistent figure

a Grades of fuel which warrant transportation, or which may be defined as "marketable," should be used with the greatest practical economy.

b The very large percentage of coal of so-called low grade which today is left at or in the mine must be utilized.

c Advantage must be taken of the large deposits of lignite and peat which are found in many sections of the country.

It is undoubtedly true that in general, under conditions which do

not require the use of steam for other than power purposes, the producer-gas power plant meets the requirements of *a*. At present the only method of advantageously handling the fuels mentioned in *b* and *c* is in the gas producer, and the utilization cf these lower grades of fuel on an extensive scale demands concentration of large power units within close proximity to the fuel supply.

W. B. Chapman. In Par. 3, among the different requirements for successful operation, is mentioned the prevention of clinkers. I think the formation of clinkers can be avoided by the prevention of blow-holes or chimneys which allow the air to blow up through the fire bed, making hot spots. The average temperature across the hot zone in a producer is seldom high enough to produce clinkers. It is only in the neighborhood of the blow-holes that a sufficient temperature is attained to form clinkers. If the excessively high temperature necessary to the formation of clinkers existed throughout the producer, a clinker a foot or so thick would form immediately across its entire width. When ashes are melted they tend to run together, forming a clinker. The way to prevent this is to agitate the fuel bed continually, just enough so that the molten ash running down cannot take a permanent set in large masses, but is constantly kept in small pieces.

2 The successful producer should keep the fuel bed at an even temperature and uniform density throughout any horizontal plane. If there is a lesser density in any particular spot, the air blast immediately makes for this spot, causing an uneven temperature. To obtain this uniform density and temperature I believe that it is necessary to use some sort of mechanical agitation by hand methods, as no man or group of men can maintain a fuel bed of uniform density and temperature throughout any given horizontal plane long enough to get satisfactory results from soft coal.

3 Another point is that the successful producer should be made in a variety of sizes. The principles used in the producer described do not seem to admit of such variety. If this producer is of large diameter, the draft will go down the walls rather than in the middle, and the upper zone will not get hot enough in the middle to drive the tar out of the coal. If the tar is not removed by high heat in the upper zone, it is sure to get to the engine.

4 A successful producer should not require a delicately balanced draft, for the "balance" is often difficult to maintain. Uniform density in the two zones is imperative in double-zone or balanced-

draft operation, as otherwise the draft will vacillate from one zone to the other according to their varying density or resistance. The density is apt to change with the loads and with change of operators. The density will also change when the ashes are removed, as during this process a cavern is often formed which drops suddenly. In a producer of this type I have seen the vacuum vary from 2 in. to 18 in. in the lower or up-draft zone, and from 10 in. to 30 in. or more in the upper or down-draft zone.

5 In Par. 21, referring to the question of varying the air supply to the engine according to variations in the heat value of the gas, Mr. Bibbins says: "But this variable factor has received practically no attention and as a consequence producer operators are working entirely in the dark." To my mind the proper way of overcoming this difficulty would be to provide suitable mechanical means for maintaining uniform conditions in the organization of the fuel bed.

H. M. Latham. I think Mr. Bibbins has struck the keynote in regard to bituminous gas producers, when he says that the primary requisites are continuous operation and tar-free gas. There is no question in my mind that these are the most important considerations. Any producer which satisfactorily meets these requirements should have a large field of usefulness.

2 We have already seen from the figures presented by Professor Fernald, that the bituminous producer is at present the predominant type, and it seems probable that future development, especially in large units, will be along this line. In New England the high cost of anthracite coal suitable for use in producers of the strictly anthracite type, offers serious objections to its employment as a fuel.

3 As regards continuity of operation, while it goes without saying that a certain reserve power should be provided, yet it is frequently convenient and desirable in installations where power is required every day in the year, to be able to operate without calling upon the reserve, or in other words, to run absolutely without interruption.

H. H. Suplee. In regard to the question of continuous operation, I think Professor Fernald will remember that we have had a number of gas producers running continuously in this country and elsewhere, not for one year only, but for a number of years, but we did not call them gas producers; we called them blast furnaces. But I hardly think we care to run our producers continuously.

2 In regard to the prevention of clinkers by keeping the contents of the producer in motion, that solution was adopted in the Kitson producer ten or twelve years ago, by means of an inclined grate which was made to revolve slowly. As a result the contents of the producer were kept moving up and down, and at no time did any clinker form. The producer was discontinued, but for other reasons. The inventor of that apparatus based it, he said, on the idea that running water would not freeze, and that in the same way, any substance would be prevented from solidifying by keeping it in continual motion.

3 It must be remembered that in the operation of gas engines, the calorific power of the gas produced is not the essential thing, but rather the value of the charge actually delivered to the cylinder; and this can be made almost anything which may be desired, the proportion of air being regulated according to the richness of the gas so as to give a charge of practically constant heating value.

E. N. Trump. In making tar-free gas all of the valuable by-products are destroyed. If Mr. Bibbins proceeds to burn up the by-products from the gas in the centre of his producer, he will lose from 80 to 90 lb. of sulphate of ammonia per ton of coal, which would pay for a large part of the coal used in his producer, if it were recovered.

2 As to continuous operation: We have had one plant burning from 150 to 155 tons of coal per 24 hours, in continuous operation for the past ten years; the pressure has never been off that plant but once, and then for a period of two hours.

3 If the fuel bed in the producer is agitated, and plenty of steam provided, clinkering is almost entirely prevented. Agitation can be produced by continuously extracting the ashes at the bottom, thus uniformly loosening the bed. Even with a very deep bed almost no poking is required.

4 Our experience has been with Hocking Valley coal, which will not coke. With coking coals it is more difficult to prevent the clinkering, but the agitation by the special mechanism for removing the ashes prevents clinkering to a great extent.

H. F. Smith. While it is of advantage to run continuously, still in most plants it is desirable to start and stop the engines. The majority of manufacturing plants run from eight to ten hours a day, and it is of equal importance to be able to shut the producer down, and to start up again in the morning with a reasonably uniform con-

dition of operation, within thirty minutes, say, of starting the plant. Whether or not the type of producer outlined here is adaptable to meet that condition is open to question.

George D. Conlee. I would like some information regarding the possibility of naphthalene formation by the gas producer. In coke-oven and coal-gas practice, if the heats are sufficiently low to prevent the formation of naphthalene, an excessive production of tar results. Either the one or the other will be present.

2 Regarding the possibility of removing sulphur from gas by reheating, in the manufacture of enriched water gas for illuminating purposes, the gas is passed through checker brick heated to about 1600 deg. fahr. The gas is then scrubbed with water, cooled and passed through iron oxide to remove the hydrogen sulphide. The passage of the gas through the checkers seems to have no effect on the hydrogen sulphide, though it may change some other sulphur compounds to the sulphide.

The Author. In presenting this paper I have had misgivings that it would be considered by some as unduly optimistic. But I hope that I have been absolved from that charge through the simple showing of facts as complete as were at my command.

2 The producer under discussion is more or less the culmination of experiments of many years on different types. It represents the work of a number of engineers who have all striven for the perfection of the bituminous type in one form or another, and I feel safe in saying that the results are such as to give us some encouragement that the problem of gasifying bituminous coal is not as hopeless as it has been supposed to be.

3 First let me define what is meant by continuous operation. While I think no commercial plant should have to shut down every fifth day to clean out, yet 365 days for the plant does not necessarily mean 365 days for the producer. Taking conditions such as normally exist in an electric light plant using steam boilers, we should expect a producer unit to run at least as long without excessive labor charge for cleaning and recharging. A small percentage of reserve equipment is always essential, but 100 per cent is certainly not required.

4 If the producer is to stand by itself, there is no occasion for especial leniency, i. e., we should demand from the designers a grade of service equal to that rendered by present steam plants, and from present indications this can be obtained.

5 These high rates of combustion—30 to 50 lb. per sq. ft. grate area mentioned in the discussion—are interesting, but it must be borne in mind that sometimes the amount of coal fired includes the additional fuel for building new fires. It is apparent from the Norton test that a very considerable proportion of the total coal fed into the producer was withdrawn at the end of a normal run, and if the heat equivalent of this fuel be deducted the rate of combustion will be lowered considerably. So, in comparing intermittent and continuous types of producers, it is necessary to take this extra fuel into account, for in the case of very frequent recharging the net loss is high.

6 The size of producer mentioned by Professor Fernald is rather extraordinary. I think not many of us realize that 3000-h.p. producers are being built. If it was a two-shell producer (the two rated as a simple unit) it should hardly be compared with the single shell producer on the same basis.

7 The sensitiveness of the balanced draft method of control has, I think, been overestimated by Mr. Chapman. While it is stated in the paper that the two control valves should be permanently set, I presume it would be recognized that these valves are put there to correct any inequalities or deficiencies in the fuel bed. When the producer is properly operated the valves need little or no adjustment, otherwise they must be adjusted occasionally.

8 I do not quite agree with Mr. Chapman's statement that it is impossible to maintain uniformity of the fuel beds with hand firing. When the plant illustrated was visited I noted this point especially by the aid of a simple apparatus. This is a double poker, consisting of a section of pipe with a solid rod through the center. By shoving both down into the fire and pulling out the rod and covering the pipe with a glass at the top, the condition could be noted. It was interesting to see that when the top of the fuel bed appeared practically dead, just under the surface it was at the proper temperature. I did not find the irregular conditions of fuel bed which Mr. Chapman mentions and I do not think it was merely a coincidence. The tendency towards short circuiting which he fears in large producers is not as marked as might be expected, excepting with wet peat, possibly owing in part to conditions.

9 As to the sulphide which Professor Rautenstrauch mentions, I can only say that it has not to my knowledge caused trouble. I have seen engines running successfully for a time on by-product coke-oven gas where it was found that by keeping the rods as hot as possible the deposition of sulphur was avoided and the consequent

corrosion of the rods. As far as I know napthalene has not created similar trouble. A napthalene formation is characteristic of the distillate process where the higher hydro-carbons form the greater percentage of the heat value.

10 It is encountered in by-product coke-oven gas to some extent. But the difficulties arising from deposition of napthalene seem to be confined to delicate measuring instruments rather than the engine valves or rods which seem to be at a temperature sufficient to dissipate the accumulation. In producers the heats are run well above the destructive point.

11 Mr. Smith seems uncertain as to the possibility of the producer under description retaining its condition over periods of daily shutdowns. Table 1 shows a period of 18 days—432 hours—during which the producer was entirely idle for 23-hour periods. After a night's shutdown 15 minutes usually suffices to bring the fire into normal temperature conditions.

12 The automatic variation in the proportion of air and gas to the engine according to the richness of gas delivered to it is a problem of engine design relating to regulation of mixture. Designers must face the possibility of variations in gas from the best producers, and I do not believe any mechanical agitation of the fuel bed will avoid this necessity. In a plant employing a 15,000-ft. mixing holder I have observed a puff of rich gas (liberated just after charging) make its way clear through to the engine at regular intervals quite destroying the mixture for the moment.

13 Mr. Trump assumes that the breaking up of hydrocarbons occasions a serious loss of efficiency not encountered in the generators of tar-laden gas. Just what are the precise reactions seems to be unsolved, but in the last analysis only one factor is uppermost—the comparative efficiency of the two systems. I doubt that much over 70 per cent is obtained from either process and less when the power consumption of tar extracting auxiliaries is taken into account.

ECONOMICAL FEATURES OF ELECTRIC MOTOR APPLICATIONS

By Charles Robbins,[1] East Pittsburg, Pa.
Non-Member

The principal object of this paper is to show, by figures and curves, based upon actual tests and investigations of existing installations, how a problem in motor drive can be handled in order to show its maximum economy. It will endeavor to show that the hourly cost of operation is dependent upon the characteristics of the various types of machine tools, from the standpoint of power and time required. The load and time factor of the tool will be taken into account and the influence of this factor on the cost of production. Data are also given upon the electric-motor equipment of machine tools, with suggestions for its standardization.

2 There are certain types of tools in which the operations to be performed require constant speed, for which service the constant-speed type of motor should be used. Other types of tools call for a cycle of duties, in which the range of speed may vary almost from minimum to maximum conditions. In these cases the adjustable-speed type of motor should be used for the greatest economy. There are, therefore, in a single shop two distinct service conditions calling for different types of motors, different methods of applying the motors to the tools, and different methods of control.

3 Where direct current is available, these conditions can be met by the direct-current motor, i.e., both a constant-speed and an adjustable-speed motor is available for machine-tool work. On the other hand, the alternating-current motor is essentially a constant-speed machine. At the present time no commercial method has been found for varying the speed of an alternating-current motor in such a way that it can be

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successfully used for machine-tool service. Thus it is apparent that the machine-tool designer must take into account not only the application of the motor to the tool, but also the class of current supply available in the manufacturing establishment in which the tool is to be used.

4 An alternative method of driving is by the use of a system of gears, commonly called a gear box, driven by a single belt considerably larger than that ordinarily employed on cone pulleys. This large belt will to a considerable extent furnish the power required, the necessary changes in speed being obtained by changing the gears. Obviously, however, a gear box arrangement cannot be as convenient of manipulation as a motor controller, which can be mounted in a position to be easily reached by the operator. In addition to this difference between the two methods of changing speeds, the motor drive offers finer gradations of speed; that is, if the same results were obtained in a gear box, the multiplicity of gears would be considerable, and the up-keep a matter to cause serious consideration.

STANDARDIZATION OF TOOL EQUIPMENTS

5 One of the great drawbacks to a harmonious design of motor and tool has been the lack of a proper understanding of the joint problems of the motor and tool builder, this condition showing the necessity of some standard in respect to speeds or speed ratios, method of control, and certain dimensions of the motor or its adaptation to the tool. There is also a lack of standardization of the method of supplying power in industrial plants. For instance, there are so-called different systems, as direct current of 110, 220 and 500 volts, and alternating current of 220, 440 and 550 volts and two or three phases; also either 25 or 60 cycles may be called for.

6 In view of the above conditions, which are in a measure arbitrary, the future developmentof the art will be materially benefited if some standardization can be adopted by the tool builder and the motor builder, whereby they may be able to recommend certain standard power equipments for metal-working establishments.

STANDARDIZATION TO ACCORD WITH CENTRAL STATION SERVICE

7 Central station power companies now realize the great advantage of a day load and are quoting low power rates to manufacturing establishments. It seems probable that in the future much of the power for small, and to some extent for large, manufacturing estab-

lishments will be furnished by central power companies, either those which are formed for the purpose of furnishing power only, or those which are regularly organized as public utility companies, furnishing both power and light. To this latter type of existing central power stations the day load supported by power service to manufacturing establishments is particularly attractive.

8 As most communities contain both manufacturing plants and central station companies, we look forward to an immense dev lopment of central power service, to be used by large manufacturers as well as by the smaller ones. For this reason we suggest that the class of service, i. e., the characteristics of the current supply, should be taken into account when making standards for the operation of metal-working tools.

9 The steam railroad companies as a class have been to a considerable extent the largest single purchasers of machine tools, and it is well to consider the power requirements of such classes of purchasers when deciding upon a standard of motor equipments for tools.

10 For some years it has been the almost universal practice of steam railroad companies to install alternating-current generator equipment in their power stations; these are principally of the turbine type, largely for the reason that their requirements are to a considerable extent similar to those of the central stations of power companies. They are called upon to distribute current for lighting their train sheds, stations and yards, and power for operating turn-tables, transfer tables, etc., and for the operation of their repair shops, which usually consist of machine and wood-working divisions. Because of the simplicity and the great desirability of alternating-current motors, the railroad companies have adopted them almost exclusively for constant-speed service, as exemplified in the machinery of their wood shops, and for miscellaneous power purposes, such as pumping, operation of fans, driving incidental sections of line-shafting for supplying power to the smallest types of tools, on which it would be inadvisable to employ individual motors, and to tools requiring constant-speed motors.

11 For tools whose operation calls for adjustable speed, the standard practice is to employ direct-current adjustable-speed motors, using a controller conveniently located to the operator in such a way that the variation from minimum to maximum speed can be made with great facility, therefore affording a ready means of obtaining the maximum output for which the tool is designed.

12 It will be evident from this practice that two kinds of current are employed—alternating current for the primary and direct current

for all secondary operations. To transform from alternating current to direct current, either a rotary converter or a motor-generator set is employed, the specific selection of one or the other depending somewhat upon local conditions and the class of supervision available for the operation of the outfit.

13 The same scheme of operation can be very advantageously employed when using central station service for the operation of machine shops or metal-working establishments in which machine tools are employed. Such a standardization of tool equipments by the tool builders and the motor manufacturers would tend to place the operation of metal-working tools on a more economic basis, in that it would enable better tool equipments to be designed with a definite certainty that the motor requirements could be forecasted. As it is now, a very considerable risk is involved in designing tools in advance of orders. Few companies manufacture motor-driven tools in large quantities and the public is thus called upon to pay a higher price because of a lack of standardization.

14 On account of the fixed conditions of central station service, it is almost universal for the service to be 60-cycle, 3-phase, and as the transmission line is of relatively high voltage, transformers will be necessary at each industrial plant, and the voltage of the motor installation can thus be suited to the requirements. In metal-working establishments, where the motors can be located on the tools, or to some extent in close proximity to the metal structure, it is desirable to use a relatively low potential, say 220 or 440 volts. Thus in a measure there has been established automatically a standard for alternating-current service, consisting of 60-cycle, 3-phase, 220-440-volt, this standard being that used by most of the largest single purchasers of metal-working tools, i. e., the steam railroad companies.

15 By the adoption of standards which conform with the central station supply service, it is evident that even in the case of very large manufacturers who have their own isolated power plants, use can be made of a so-called break-down connection with the central station power company, as an extra precaution to insure continuity of service. This break-down connection can be made available only when the service supply is uniform with that employed by the isolated plant. Connection to a central power company would prove a very great advantage to a manufacturer for overtime work, when but little power is usually required, or under conditions when but a small percentage of tools are in operation as it would permit closing down the isolated plant, and the operation of the limited service from the outside power system.

16 This standardization of tool equipments would also enable existing manufacturing plants not equipped throughout for electric driving, but requiring the service of machine tools, to make trial installations of motor-driven tools or of a rapid-production tool, in which much of the advantage to be gained is due to the motor drive.

ANALYSIS OF OPERATING CONDITIONS

17 It is only recently that data have been available to show beyond doubt the intermittent operation of the average machine tool. When a machine shop is driven by a belt from engine to lineshaft, and from lineshaft to machine tool, it is difficult to determine with any degree of exactness the length of time any particular tool is in operation, or the average time of operation during the working day.

18 With the installation of motors on lineshafts, it became evident that the total horsepower capacity of motors was much in excess of the power generated in the power station. This ratio is sometimes three to one, other times possibly four to one.

19 As individually driven tools are adopted it is noticed that the total horsepower capacity of all the motors connected to the service grows very rapidly, and that the ratio of the connected capacity to the power supplied is often as high as five or six to one, indicating that the time-load factor of the average machine tool is relatively low.

20 This apparent difference between the connected capacity of motors and the demand on the power station has led to a careful analysis on the part of the motor builders to determine exactly the length of time tools can be expected to be in operation.

21 An analysis which took into account the time of loading, cutting, unloading, and other delays occasioned by miscellaneous causes, showed conclusively that it was not necessary to use a continuously rated motor; in fact, an intermittent rating on the motor for a period not exceeding two hours' continuous service answers for almost all kinds of machine tool applications. This knowledge enabled the motor manufacturer to build a more economical motor, one of smaller size, and consequently reduce the expense of applying motors to machine tools. The present-day tool equipment ought not, therefore, to be much more expensive, if any, than that of the belt-driven tool, when the cost of belting, shafting and power house equipment is considered.

22 When machine tools are equipped with individual motors, a graphic recording meter may be connected in the motor circuit, making it possible to have a complete log of the operation of the particular

tool during its time of service. The chart furnished by the graphic meter will show the time of loading and unloading the tool, the time of cutting, all delays due to stoppage for one cause or another and the amount of power to operate the tool, which is a direct function of the work done.

23 Fig. 1 shows a graphic recording meter by which interesting tests have been made in studying machine tool operations. The instrument is unlike an indicating meter, in that instead of a needle

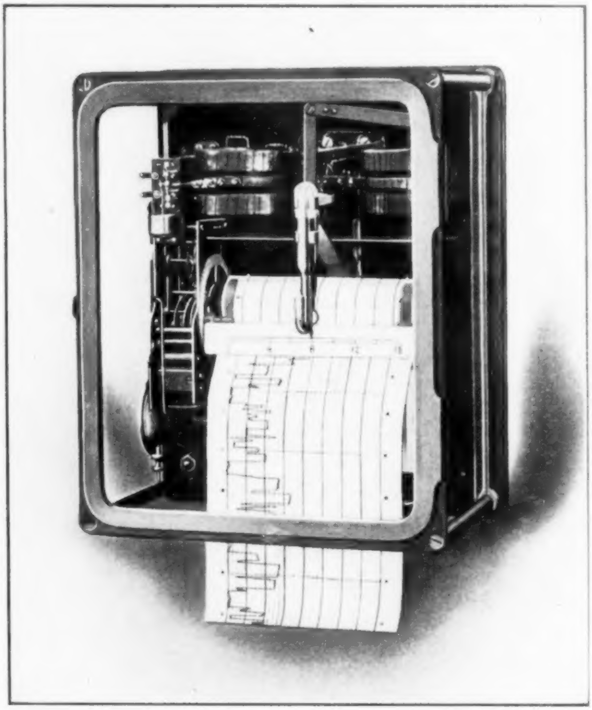


Fig. 1 Graphic Recording Meter

passing over an indicating scale, the meter is provided with a pen moving horizontally, thus making a line on a properly graduated roll of paper. The paper is moved by clockwork, vertically, and at right angles to the pen, so that a permanent record of the magnitude and time of all operating changes is obtained.

24 A time study can be made from each tool from these charts, and knowing the theoretical time for the job an analysis can be made of the

curve, furnishing information that will enable the foreman to increase the productive capacity by the elimination of delays. He will also know whether or not the tool has been working at its maximum capacity, whether the tools have been kept up to standard conditions, and in general can apply the necessary remedies.

The Economics of Motor Drive as Determined by the Actual Performance of the Tools

25 The economy of the individual motor drive, due to the fact that practically the exact cutting speed can be obtained for any operation, has been pointed out. This economy is not so important, however, as that of keeping a tool in continuous operation through longer periods of time, by reducing the time required for handling and other avoidable delays, as previously mentioned.

26 The accepted method of capitalizing motor drives seems in general to be on the basis of the incidental savings in the workman's time. In our opinion this is not the whole story by any means. When determining the monetary advantage of motor drive, the value of time saving should be considered on the basis of its effect on the total cost, which includes the workman's labor and the investment cost per hour of the tool.

27 In addition to workmen's wages, every shop has the following expenses:

a Interest and depreciation on cost of buildings and accessories.

b Repairs and renewals to existing equipment.

c General operating expenses, including losses due to defective workmanship, design and material.

d Salaries of supervisors, engineering staff and clerks.

28 These overhead charges must be included in the cost of any manufactured article. A method frequently employed is to determine from time to time the percentage which the total overhead charge bears to the cost of total actual or productive labor. This percentage in large shops reaches from 100 to 200 per cent, or even more. The total labor charge is then obtained by multiplying the actual labor cost by one, plus the per cent to be added for the overhead charge.

29 This is an easy way to take care of the overhead charge; but the method is inaccurate and does not show the relative importance of different types and sizes of machines. This statement is especially true where a great variety of materials is manufactured, in shops using a

large number of different types and sizes of tools. Under such conditions, the precentage obviously varies within wide limits for different kinds of work.

30 A satisfactory method of distribution is to set off against each tool its proportion of the total overhead charges. The portion chargeable to each tool depends entirely on local conditions; and thorough amiliarity with these conditions is needed in order to apportion these charges equitably. In this way, the relative importance of each machine is taken care of.

31 In a shop where only one type of article is manufactured, and the castings are passed from one machine directly to the next, a simple and logical way is to divide the total overhead charge among the tools, in proportion to the floor space charged to each tool. In the majority of shops, however, the above simple condition does not exist; several sizes and kinds of articles are usually turned out, and various sizes and types of tools, differing greatly in their operating characteristics, are employed. In such cases, not only must the floor space be considered, but also the time each tool is actually in operation, the nature of the work and the amount of supervision and engineering attention needed.

32 Large shops handling different classes of materials are in most cases divided into various departments or sections, and each section may be considered as a separate smaller factory. The overhead charges against each department may thus be apportioned among its tools in proportion to the floor space occupied, making proper allowance for special local conditions, or special supervision or engineering attention. Here again is required thorough familiarity with both the engineering and the shop features of the materials manufactured.

33 In our experience we have found the overhead charges to be approximately as follows:

Variable charges	from 50 to 55%
Salaries	from 25 to 30%
Interest on cost of machine tools	from 5 to 10%
Depreciation on cost of machine tools	from 5 to 10%
Fixed charges	3%
Power	from 1 to 2%

The detail method of arriving at these general figures is found in Appendix 5.

DEFINITIONS OF TERMS

34 In discussing the economics of motor drive there will be a number of terms used which are here given with our interpretation of their meaning.

Applied to the operation:

Time factor = ratio of actual cutting time to total time required to complete a machining operation

$$= \frac{\text{Actual cutting time}}{\text{Total time to complete operation}}$$

Applied to a Machine Tool:

$$\left.\begin{array}{l}\text{Time factor}\\ \text{in per cent}\end{array}\right\} = \frac{\text{Total daily actual cutting time in hours}}{\text{Total number of working hours}} \times 100$$

Average running load = average input to motor while operating, usually expressed in kilowatts, but may be expressed in percent of full load input.

For rough calculations in this paper the input of a motor in kilowatts is assumed to be the same as the output in horsepower; that is, the motor efficiency in all cases is assumed to be about 75 per cent. This low percentage will take care of the fact that motors operate at light loads a considerable part of the time.

Maximum load = maximum input to motor, expressed in same terms as the average running load.

Average load = *Average daily load* = average input to motor during the total working hours; usually expressed in kilowatts. This load multiplied by the total number of working hours gives the total kilowatt hours consumed per day, and is the basis of payment for energy. The average load multiplied by the number of hours per day and by the price per kilowatt-hour gives the cost of energy per day. The average load also equals the average running load multiplied by the time factor.

Load factor = the ratio in percent of the average daily load to full load rating of the motor, or

$$\text{Load factor} = \frac{\text{Average daily load}}{\text{Full load rating of motor.}}$$

CONDITIONS ENTERING INTO THE OPERATION OF A MACHINE TOOL

35 In order to obtain a maximum output from a machine tool, a careful analysis must be made of all the conditions entering into the operation of the tool. One method of doing this in the case of a motor-driven tool is to take power readings at frequent intervals and lay

these out on a chart basis. Another and a much more convenient method is the employment of a suitable meter, as already described, designed to make a graphic curve, showing the exact condition occurring in the service when such a meter is applied to any motor-driven tool.

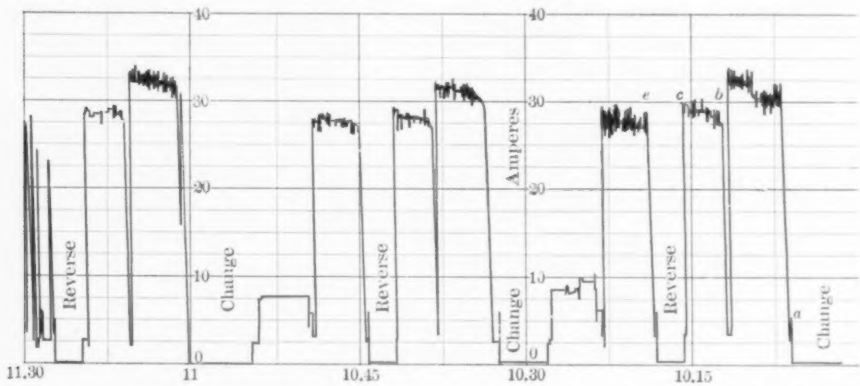


FIG. 2 METER RECORD WHEN TURNING SHAFTS SHOWN IN FIG. 3

36 Fig. 2 shows a record obtained while shafts of the dimensions shown in Fig. 3 were turned from machinery steel. Both Fig. 2 and Fig. 3 are lettered for reference. The records read from right to left, as indicated by the time at the bottom of the curve in Fig. 2. The vertical coördinate is in amperes, the full scale being 50 amperes. This current at 220 volts corresponds to 11-kw. input to the motor. At the extreme right, the record indicates zero power; that is, the motor was standing idle.

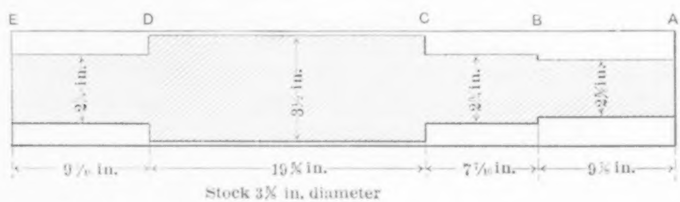


FIG. 3 SHAFT OF MACHINERY STEEL

37 During the interval marked "change," the stock to be turned was placed in the chuck of the lathe. At *a* the current increases for a

very short interval to about 3 amperes, while the lathe was running idle. The current then suddenly increases to about 30 amperes, due to the fact that the cutting tool was fed against the stock and the cut started. The current remains at this value for a period of about five minutes while the cut AB is taken, changing the diameter of the stock as indicated in Fig. 3. At b the current drops to three amperes, the motor running idle while adjustments of cutting tools are made. The current then increases to 28 amperes while the cut BC is taken. At c the machine is stopped to reverse the half-completed shaft for machining the opposite end. At e the machine is again started and the current increases to 27.5 amperes while the cut ED is taken. Another adjustment of the diameter is then made, the machine running idle for a short interval. From 8 to 10 amperes are required when the final cut DC is taken, after which the machine is stopped to remove the completed shaft. A similar cycle is repeated when the next shaft if turned.

38 The record shows three completed cycles, covering the time required to complete three shafts At 11.15 a.m., before taking the cut ED, there are sudden fluctuations of current; the form of the curve compared with other cycles shows clearly that some trouble was encountered with the cutting tool or work, and the adjustments made. The record also shows the delay in time.

TABLE I. ANALYSIS OF TIME AND POWER OF A LATHE OPERATION

Shaft	Time	Mins. Amps.	Cutting				Mins. %	Total Cutting	Change	Reverse	Adj. Tool	Misc.	Comp.	Time Factor	Load Fact.
			AB	*BC*	*ED*	*DC*									
1	7.30	Mins.	5.1	3.7	4.9	4.9	Mins.	18.6	5	5	12.0	21.2	61.8		
		Amps.	23	22	22	5	%	30	8.1	8.1	19.5				
2	8.05	Mins.	5.3	3.9	4.4	4.4	Mins.	18.0	4.7	2.4	4.4			30	12
		Amps.	25	23	24	5	%	61	15.9	8.1	14.9		29.5		26
3	8.30	Mins.	5.0	3.7	4.8	4.6	Mins.	18.1	7.5	2.4	1.9			61	
		Amps.	29	25	24	7	%	60.5	25	8	6.4		29.9		
4	9.05	Mins.	4.5	3.4	4.8	4.7	Mins.	17.4	3.2	8.9	2.3			50.5	26.5
		Amps.	31	29.5	24	6	%	54.8	10	27	7.2	27.1	31.8		
5	10.05	Mins.	5.1	3.8	4.5	4.7	Mins.	18.1	5	2.5	1.3			54.8	25
		Amps.	29	26	25	6	%	33.5	9.3	4.7	2.4		54.0		
6	10.30	Mins.	4.9	3.6	4.6	4.9	Mins.	18.0	4.3	2.4	2.0			33.5	14.6
		Amps.	28	25	25	5	%	67.5	16.1	9	7.5		26.7		
7	11.00	Mins.	5.0	3.7	5.4	5.1	Mins.	19.2	5.5	2.6	2.7			67.5	25
		Amps.	29	26	24	4.5	%	64	18.4	8.7	9		30.0	64	27

39 Table 1 is a summary of the data obtained from the graphic record, part of which is shown in Fig. 2. Observations of cutting

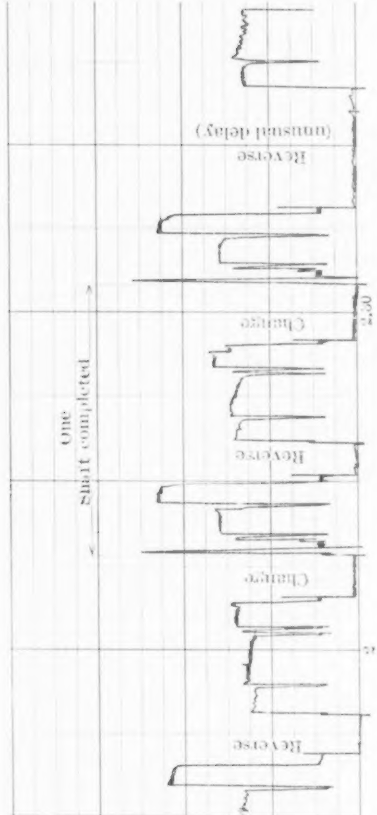


FIG. 4 RECORD MADE WHEN TURNING A LIGHT SHAFT WHICH COULD BE PLACED AND REMOVED BY HAND.

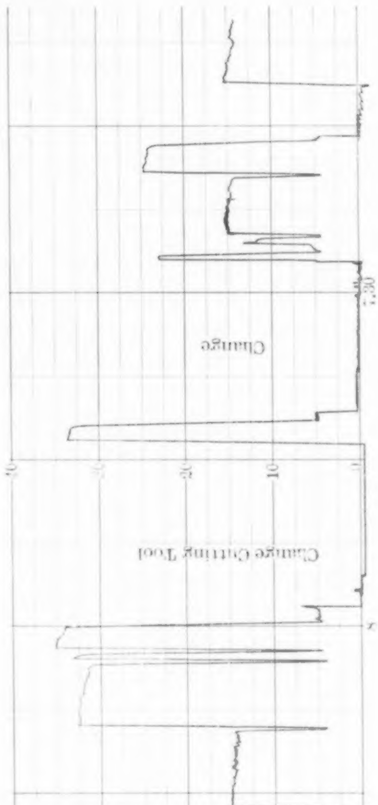


FIG. 5 RECORD MADE WHEN TURNING A HEAVY SHAFT WHICH REQUIRED A CRANE FOR HANDLING

speed and feed were taken at the lathe. The cutting speed used while turning these shafts was 55 to 60 ft. per min. The feed while taking the cuts *AB*, *BC*, and *ED* was 0.04 in. per revolution, and while taking cut *DC* was 0.077 in. per revolution. The normal time to complete a shaft was from 27 to 32 min. In case of shaft No. 1 the time was 62 min.; this was the first shaft turned after starting work, and preliminary adjustments, oiling lathe, etc., consumed 21 min.; 12 min. were required to adjust the cutting tool. In the case of shaft No. 5, 54 min. were required on account of a 27-min. delay. The amperes referred to in Table 1 are those below the 3 amperes required to run the machine idle; they are, therefore, a measure of the power required to remove the metal. The time factor averages 53 per cent; its maximum value is 67 per cent, and its minimum value is 30 per cent. The load factor is 25 per cent under normal conditions.

40 It must be obvious that, with a given rate of cutting, the fewer the delays, the higher will be the time factor. The magnitude of the records is an indication of the rate of removing metal, as will be further explained.

41 By means of this meter record it is possible to discover all delays, and to check the rate of cutting metal. Those are the two fundamental factors which determine the rate of output on machine tools. Any deviation from the standard cycle of operation is at once detected from the form of the record. Observations of cutting speed and feed need be taken in only one case. The record will not only show the deviation therefrom, but will also indicate whether the modification is an improvement or a drawback to the rate of output. Fig. 4 and Fig. 5 show two records taken on the same roughing lathe, operated by the same man, but turn ng two different shafts. The shaft turned while making the record shown in Fig. 4 was light, and could be removed and replaced in the lathe by hand. That turned when the curve in Fig. 5 was obtained was heavy, and required crane service. The greater intervals between cutting operations, so apparent in the case of Fig. 5, were due to delays in obtaining crane service to handle the heavy shaft.

42 Records taken during several days of operation showed an average of 5 min. longer time required for every change and reversal when made by crane. This condition was remedied soon after making the test, by installing a jib crane next to the lathe, and the time to complete the larger shaft was thereby reduced from 55 min. to 45 min., a saving in time and cost of about 20 per cent. The overhead charge against this tool (see Appendix 5) was 60 cents per hr., or \$6 per 10-hr. day. The operator received \$3.50 per day, making a total daily

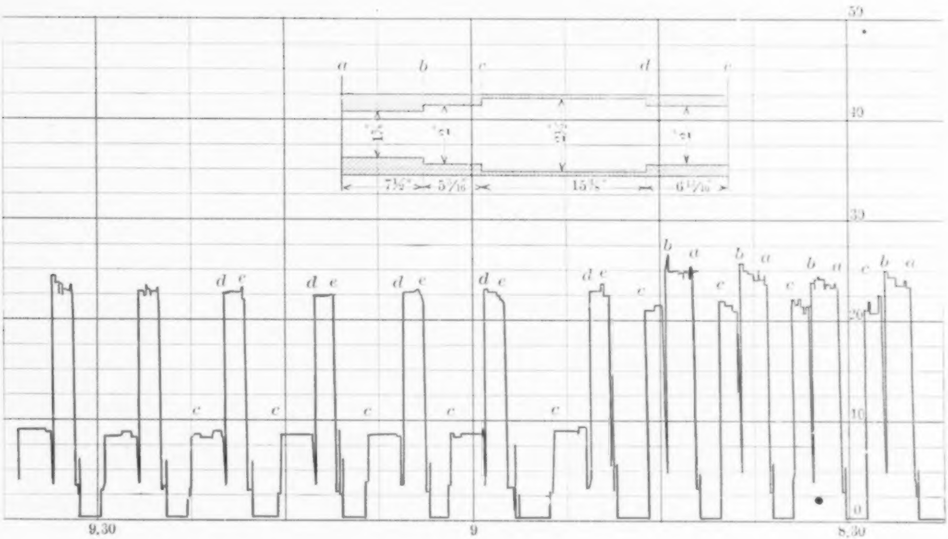


FIG. 6 RECORD WHEN TURNING THE SHAFT SHOWN IN THIS DIAGRAM

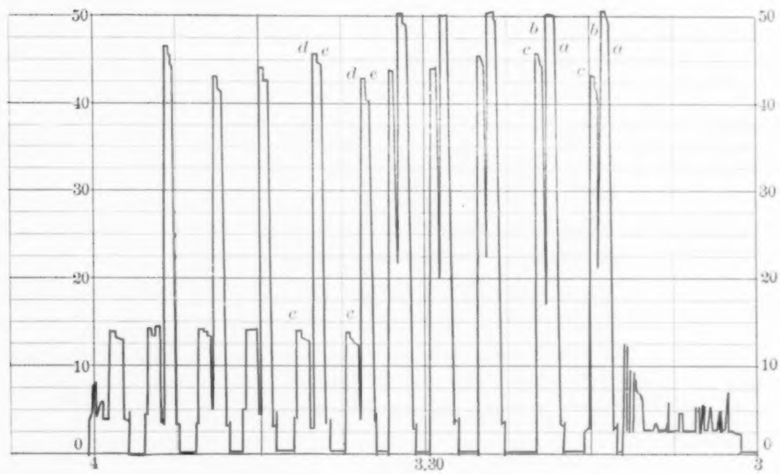


FIG. 7 RECORD WHEN TURNING THE SAME SHAFT AT DOUBLE THE CUTTING SPEED

expense of \$9.50. Before the jib crane was installed ten shafts were completed per day, making the cost of actual labor and overhead tool charge \$9.50 divided by 10, or 95 cents per shaft. After the improvement, 12 shafts per day were completed with the same overhead charge, thus reducing the labor and overhead tool charge to 79 cents per shaft.

43 Such a delay seems self-evident, after it has been discovered, but in a large shop where everybody is busy small delays are ea ily overlooked. An automatic recording meter reveals delays caused by grinding and replacing tools, etc., besides those just indicated.

44 The elimination of delay, however, is not the only advantage to be obtained from the use of a recording meter. Fig. 6 and Fig. 7 are meter records which show rates of cutting on a shaft with the dimensions given in Fig. 6. In Fig. 6 the cutting speed was 50 ft. per min. The feed for cuts *AB*, *BC* and *ED*, was 0.05-in. per revolution, and for *DC* was 0.072 in. per revolution. The same feed was employed for corresponding cuts in Fig. 7, but the cutting speed was 100 ft. per min. It will be noted that the current above friction load in Fig. 7 is double that required for similar operations in Fig. 6. The saving in time is clearly shown. An analysis of records of this kind, taken over a period of several days, gives a means of determining the most economical feeds and cutting speeds to employ on a given operation.

TABLE 2. TIME FOR ROUGHING SHAFT, EXTREME CONDITIONS

	Average Condition		Best Conditions		Poorest Conditions	
	Minutes	Per Cent of Total Time	Minutes	Per Cent of Total Time	Minutes	Per Cent of Total Time
Removing and replacing shafts	6.0	38	2.8	23	14.9	50
Adjusting tool	1.7	11.0	1.4	12	6.7	22
Cutting	8.0	51.0	8.0	65	8.4	28
Total	15.7	....	12.2	....	39.0	....

45 Table 2 shows the time relation between the various operations in roughing the shaft, outlined in Fig. 6. Approximately the same conditions were found with shafts of other characteristics. The time factor of lathe operation for this class of work is thereby shown to vary from 25 to 65 per cent, the average being about 50 per cent.

46 An investigation by personal observations over a short period of time often leads to erroneous results, as is shown by the following

experiments: In turning shafts on a roughing lathe, the first trial was with a cutting speed of 80 to 100 ft. per min., and a feed of 0.026 to 0.044 in. per revolution. In the second case, a cutting speed of 40 to 50 ft. per min. at a feed of 0.05 to 0.07 in. per revolution was employed. A single job could be completed in either case in 16 min., 12 min. being required for cutting. However, the average time per shaft, during several days operation, was 22.6 min., with the higher speed, and 21.6 min. with the slower speed. The same number of cubic inches of metal per minute was removed in each case; but with the higher speed, more frequent regrinding of tools was necessary, resulting in more delays and giving the lower speed five per cent advantage in time saving.

SUMMARY OF THE USES OF THE GRAPHIC RECORDING METER

47 By means of the graphic recording meter, the following improvements in shop management can be effected:

a If individual motors are used to drive machine tools, the exact percentage of total working hours consumed in actual cutting can be determined; it is found to average from 40 per cent to 50 per cent, the maximum being as high as from 60 per cent to 65 per cent where the cut is of long duration; the minimum from 20 per cent to 30 per cent where jobs are short and the delay long in waiting for material, drawings, etc.

b The meter reveals all delays and suggests measures for eliminating those not essential and reducing all others to the minimum, thus materially increasing the time factor. All delays shown should be accounted for, and an attempt made to avoid them. Common delays are in assignment of the next job, in obtaining drawings, tools and other necessary materials, and in waiting for crane service.

c The rate of cutting indicated by the power consumption of motor-driven tools can be checked with a recording meter. The maximum rate is limited only by the nature of the work, the strength of the machine tool and of the cutting tool.

d The rate for maximum economy can be determined for different classes of work; and the records, considered as standard, can be compared with other operations of the same

character to see whether the proper rates of cutting were used. In a finishing operation the rate depends upon the accuracy required. A record can be made while an expert machinist does the job, and this record should be referred to when other jobs of similar character are machined.

48 By the use of curve-drawing meters, and a careful study of the data obtained, the superintendent of a shop in which the individual motor-driven system is employed can set a limit fair both to employer and employees, for roughing, finishing, adjusting and setting-up. Different methods of doing the same job can be compared to determine which is the most efficient.

49 The graphic meter need not be located near the machine to which it is connected, but may be placed in the foreman's office. Small leads connected to a shunt, or to a series transformer, according to whether direct current or alternating current is employed, are all the wiring required. The wiring can be so arranged that the connections of the meter can be readily transferred to any one of several tools; thus a single meter can be made to serve a group, or any number of tools, depending somewhat upon the frequency with which the records are required.

50 So far we have dealt chiefly with the time required to do machining operation, time being a most important consideration with shop managers and those who use machine tools. The power consumption, however, is also of some importance, especially to those requiring motors for machine tool operation.

RELATIVE ECONOMY OF LINESHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE

51 An increase in economy of operation of manufacturing machinery can be effected in two ways: first, by reducing the power required to operate the machinery, by saving of friction load, etc.; second, by reducing the time required for a given operation, or, in other words, increasing the output in a given time. When confronted with the problem of deciding between the continued use of an existing lineshaft drive, or an individual motor drive, or when deciding between the two methods for a new installation, the problem should be considered in all its phases, as outlined in Table 3. This table includes every important item to be considered, except one; and in every case the advantage is with the motor.

52 Comparing the first cost is possibly the first consideration to enter the mind of most men, and this is the one consideration omitted from Table 3. That this consideration is relatively of minor

TABLE 3. COMPARISON OF LINESHAFT DRIVE AND INDIVIDUAL MOTOR DRIVE FOR MACHINE TOOLS

Item	Lineshaft Drive	Individual Motor Drive	Advantage of Individual Motor
1 Power consumption	Constant friction loss in shafts, belts and motor, power for cutting	Friction loss (motor and tool only); useful power only while working	Less power required
2 Speed control	No. speeds = no. cone pulleys × no. gear ratios	No. speeds = no. controller points × no. gear ratios	More speeds possible; time saved in speed adjustments
3 Reversing	Clutch and crossed belt	Reversible controller	Time saved in reversing
4 Adjusting tool and work	Stopping at any definite point, very difficult	Can be started in either direction and stopped promptly at any point	Time saved in setting up and lining up
5 Speed adjustment	Large speed-increments between pulley steps	Small speed-increments between controller steps	Time saved by obtaining proper cutting speed
6 Size of cut	Limited by slipping belt; large belts hard to shift	Limited by strength of tool and size of motor	Time saved by taking heavier cuts
7 Time to complete a job			Much less time required as indicated for previous items
8 Liability to accidents	Slipping or breaking belts; injury to machine tool; cutting tool or prime mover	Injury to machine tool, cutting tool or motor	Much less liability to accidents
9 Checking economy of operations	Close supervision required; very difficult to locate causes of delay	Accurate tests possible by means of graphic meter which records automatically all delays and rate of cutting	Causes of delay and remedies easily located without personal supervision
10 Flexibility of location	Location determined by shafting, and changes difficult	Location determined by sequence of operations; changes readily made	Greater convenience in handling and increased economy of operation; more compact arrangement possible

importance will be evident, when the saving in power consumption, and in time, made possible by individual motors, has been considered.

SELECTION OF MOTOR AND TOOL EQUIPMENT

53 In the selection of a motor-driven tool, there are certain features which should be taken into account and properly analyzed, and specifications drawn to cover them. If a tool is for specialized manufacturing, there should be specified:

a The exact class of work which the tool is to accomplish.

b If the power required to remove the metal is not known, then a statement should be made as to the approximate feed and cutting speeds to be taken.

c Careful analysis should be made of the time required to load and unload the machine, to determine the feasibility of employing auxiliary means other than manual labor for loading the tools.

d From this information, an approximate determination can be made as to the intermittency of operation of the tool, in order to decide whether an intermittently rated motor or a continuously rated motor will be required.

e By a knowledge of the physical shape of the work, determination can be made as to whether an adjustable-speed motor will result in economy of time, if used on this particular class of tool.

f Will enable the tool builder to determine upon the proper type of controller, and its most desirable location from an operating point of view for the workman.

54 If a special type of tool is not desired and it is preferable to purchase one with such characteristics that it can be used for general manufacturing, one should determine as nearly as possible the range of material or work for which it will be used in straight manufacturing operations. A knowledge of this will undoubtedly permit of a better motor and tool selection, than the simple purchase of a standard stock tool.

55 It should be realized that under present schemes of operation few tools are in operation more than 50 to 60 per cent of the time, whereas, the load factor of those tools may be as low as from 10 to 40 per cent. Thus we have it brought home to us clearly that much of the time the tool is in idleness and is often operated much less than its maximum capacity.

56 The direct-current motors are built for speed adjustment over a range of 1 to 2, 1 to 3, and in some instances 1 to 4. With the proper selection of controller the speed adjustments may be made in small increments of from 10 to 15 per cent, and since these small increments of speed adjustment are available, it is essential that a controller be selected of such type that it can be mounted conveniently to the operator, so that he may take full advantage of them.

57 Where it is necessary to employ the alternating-current motor, it may be absolutely essential to employ a gear box to obtain the various speed adjustments. When such a machine is employed, the fine gradation of speed obtainable with a direct-current adjustable speed motor is absent, and the gear box will practically take the place of the ordinary cone pulley arrangement. It has, however, one advantage when motor-driven, and that is, that the tool is supplied with positive power at a l times, and will take care of the maximum conditions without slipping or loss of power, which frequently occurs when belt drive is used. In some instances it has been found possible to make good use of the so-ca led multi-speed alternating-current motor. This form of motor consists in certain different types of windings, permitting of a multiple method of pole grouping, such as for instance, a speed of 1800, 1200, 900 and 720 r.p.m., according to the method of winding the motor. In some cases, this type of constant-speed motor, when used in conjunction with a gear box, will permit of somewhat finer gradations of speed than are possible with a constant-speed alternating-current motor and a standard gear box.

58 While it is apparent that with the constant-speed motor all of the advantages of the adjustable-speed motor cannot be obtained, a tool equipped with either type has the advantage to be derived from the ability to obtain a graphic log of the time of operation of the tool. With either type, in combination with a graphic recording meter, a distinct gain can be made over a belt-driven tool from which such graphic curves cannot be conveniently obtained.

59 In Appendix 5, there are the segregated charges, which must in some manner be taken into account in determining the cost of a machine tool hour, not only including the workman's time, but also the actual expense to a manufacturing establishment of having a tool equipped and ready to be used when the workman requires the services of such tool. Table 2 of this appendix will show the range of the tool-hour rate, from which it is evident that it is far in excess of the labor rate for that tool; consequently, any time which can be saved in keeping the tool in its maximum productive capacity will far outweigh any

saving that can be made in the actual labor account. It is this one feature in which the motor-driven tool in combination with the graphic recording meter is destined largely to decrease the cost of machining operations when the records available by this combination are carefully studied and proper remedies applied.

GENERAL CONCLUSIONS

60 The economical operation of a machine shop requires a thorough analysis of all the operating costs; that is, overhead and operating charges of all kinds, and an accurate knowledge of the operating conditions of all machine tools. Investigations of these conditions must be conducted by someone familiar with both the engineering and the shop features of the apparatus manufactured. The investigator should also be familiar with the characteristics of the various types of motors and methods of control, in order that the most advantageous electrical equipment as well as the best machine tool equipment may be installed, with suitable tools for different sets of conditions.

61 Such investigations lead to the following improvements which result in increased productive capacity:

a More flexible arrangement of tools.

b Greater facilities for handling materials at the tools.

c Greater facilities for handling materials between tools.

d Better facilities for obtaining auxiliary material, drawings, tools, etc.

e Better facilities for making adjustment of the tools during machinery operation.

f Removal of causes of unsuspected or avoidable delays due to small accidents and improper characteristics of the drive.

g All lost time, due to whatever cause, and which can be avoided, is immediately brought to the attention of the superintendent, and an analysis of these losses will result in their elimination.

62 With motor-driven tools this analysis can be made much more conveniently and with less expense than can similar studies with any other form of machine-tool drive.

63 While in many shops there are elaborate systems of time keeping, with time clocks, etc., all of which are based on keeping an exact record of the workman's time and seeing that he works the maximum

or full shop time, yet the most important consideration in manufacturing with machine tools is that the tools shall operate their full capacity, on account of their greater hourly value.

64 In comment on this conclusion it may be said that our tests have not been confined to metal-working tools, etc. We have found similar conditions in the wood-working industries, to some extent in cement mills, steel mills, brass and copper rolling mills, to a less extent in the textile mills, where it is a supposition that every machine is running the maximum number of hours, and at its maximum load at all times; and in several minor industries, in which the information therein contained is no less important, even though it might be different than that obtained with machine tools or metal-working tools, as ordinarily installed.

65 Certain it is, that a careful analysis and study of conditions which are conveniently possible in motor-driven establishments will greatly reduce the cost of operation, and it seems reasonable to suppose that the methods herein illustrated may serve some useful purpose if the data will arouse an interest on behalf of those present.

66 We know that wherever the tests have been made, that the conditions of operation have been very materially benefited, and feel without question of a doubt that many dollars ha e been saved on account of the knowledge shown by a simple record taken from motor-driven machines, which records are available to all those who have these meters.

67 The writer wishes to acknowledge his indebtedness to Mr. A. G. Popcke, who has made the tests herein illustrated, and who has supplied some of the information contained in the paper, and without whose coöperation the information herein submitted would not be available.

APPENDICES

The five appendices which supplement the paper pertain to the following subjects:

(1) The characteristics of various machine tools as shown by diagram from recording meters;

(2) Data on the power required to remove metal under the conditions set forth in the appendix, together with convenient charts for determining the various factors mentioned;

(3) A summary of the average horse power equipment for different types of tools and the approximate speeds of the motors, which

are normally selected for this work, the figures given are for average conditions only and are not applicable to the heaviest types of tools. In some instances, also, the motors called for are larger than would be used for tools of several years ago. The object of the figures is simply to indicate approximately the sizes of motors usually specified;

(4) Calculation to determine whether it is more economical to equip an old machine with a motor or to purchase a complete new motor-driven equipment.

(5) Over-head charges and machine hour rates.

APPENDIX NO. 1. POWER ANALYSIS OF MACHINE TOOLS

The results which follow were obtained from graphic meter records from certain machine tools under the conditions specified. These examples are given to show the characteristics of the power and the time factors that enter into the performance of machine tools of different types. (In connection with this Appendix see definitions of terms in Par. 34 of the paper.)

VERTICAL BORING MILLS

2 In Fig. 2 which follows is a record from a 72-in. boring mill equipped with a 220-volt adjustable-speed motor, 780 to 1560 r.p.m., 8.5 h.p. (assumed input at full load 8.5 kw.), taken while the tops of bronze discs were turned off and bored out. The vertical lines at frequent intervals show where the motor was started and immediately stopped, in order to make adjustments

TABLE 1 OPERATING CONDITIONS OF 72 IN. VERTICAL BORING MILL

Test No.	Time Factor %	Average Running Load		Max. Load		Avg. Kw. per Hr.	Load Factor
		Kw.	% Full load	Kw.	% Full load		
1	35	1.8	21	7.7	90	0.63	7.5
2	56	2.0	24	8.8	103	1.1	13.5
3	62	2.8	33	8.8	103	1.7	20.5
4	46	2.8	33	6.6	78	1.3	15.
5	28	2.2	26	7.7	90	0.62	7.5
6	37	2.2	26	8.3	98	0.81	9.5
Avg.........	44	2.3	27	8.0	94	1.00	12.

by moving the table of the boring mill a short distance. The gradual decrease in power after 9 a.m., and also after 3 p.m., shows improper use of the controller. The tool was fed towards the center of the mill, thereby gradually decreasing the diameter of the work. The motor was evidently allowed to run at a constant speed, while the speed should have been gradually increased to compensate for decreased diameter of work, and thereby keep the cutting speed constant. The controller was arranged to give the required speed adjustment, and failure to take advantage of this feature caused loss of time. In one

instance the records showed that 10 min. was consumed for an operation which could have been performed in 6 min., if the cutting speed had been kept constant, a saving of 40% in this operation. In another case, the time taken was 15 min., and would have been 9.5 min. with a constant cutting speed, which would have resulted in a saving of 37%.

3 While taking roughing and finishing cuts on this boring mill, from castings of motor frames, brackets and end plates, the conditions were found to be as in Table 1, from which the following summary is obtained:

Average time factor..44%
Average running load ....2.7 kw., or 27% of full load
Maximum load, sustained for several minutes . .8 kw., or 94% of full load
Maximum load peak ....8.75 kw., or 103% of full load
Average load ....1 kw., load factor 12%

CHARACTERISTICS OF RADIAL DRILLS

DRILLING AND COUNTERBORING

4 Table 2 was made up from records taken upon a 10-ft. radial drill driven by an induction motor of $7\frac{1}{2}$ h.p. 720 r.p.m., obtained when cast-steel pole shoes were counterbored, as indicated in Fig. 1.

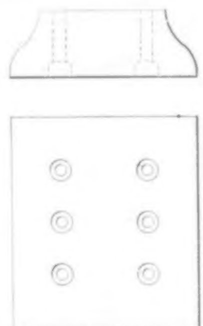
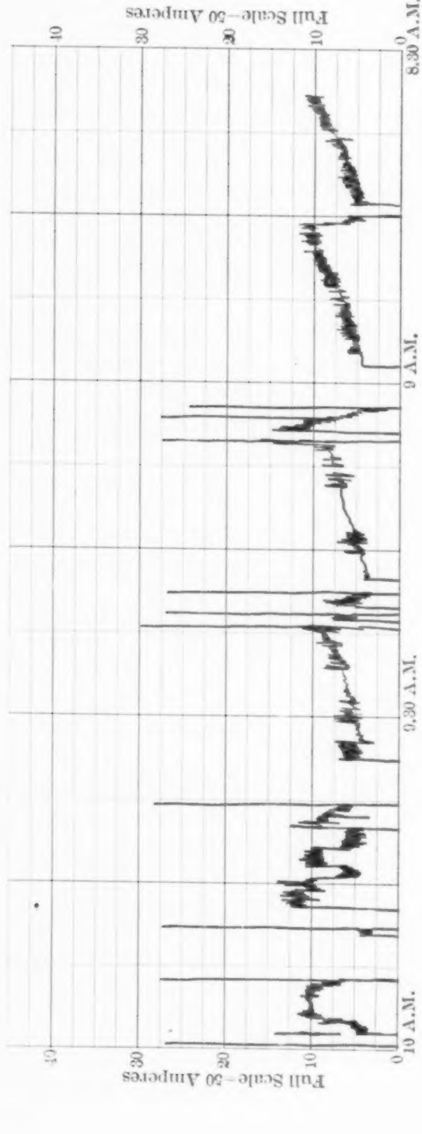
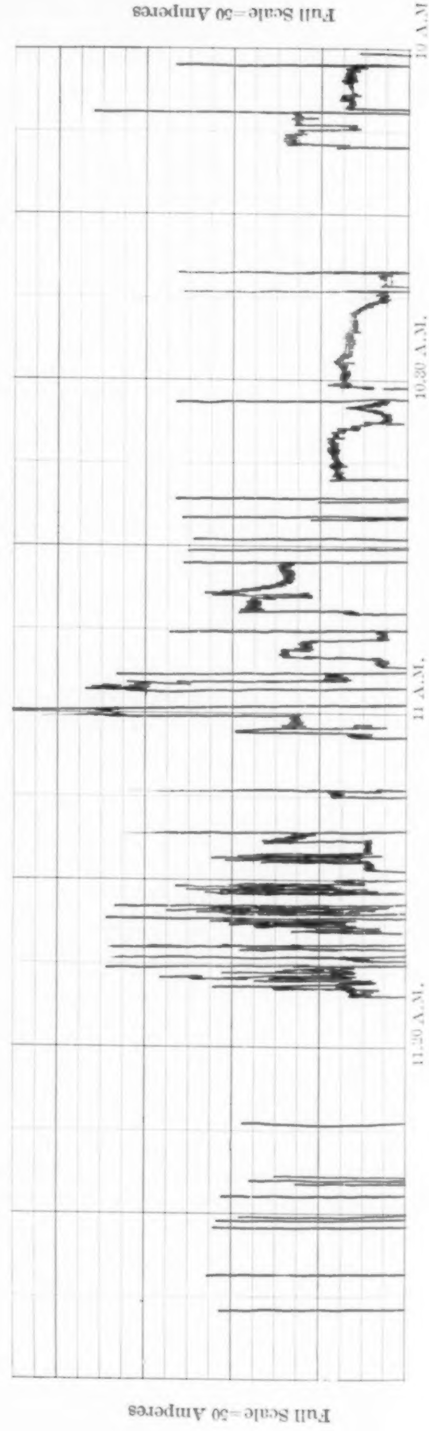


Fig. 1 Pole Shoe, Drilled and Counter Bored

5 The record (not here printed) shows $7\frac{1}{2}$ min. required to counterbore each of the six holes per pole shoe. The sum of these is about 44 min. The total time for adjusting the drill is given under column headed "Adjust," and was from 15 to 24 min. for each pole shoe. The time consumed in removing and replacing the shoes in the clamps is tabulated under column headed "Change." This ranged from $7\frac{1}{2}$ min. to 10 min. The time to complete counterboring each pole shoe varied from 70 to 75 min. The actual cutting or drilling time was from 57 to 64% of the total time to complete a pole shoe. From 10 to 14% of the time was consumed in changing the shoes, and from 22 to 33% was consumed in adjusting the drill. The average power consumed was 2.8 kw., making a load factor of about 37%.


Full Scale—50 Amperes
0
10
20
30
40
8.30 A.M.
9 A.M.
9.30 A.M.
10 A.M.
Full Scale=50 Amperes


Full Scale=50 Amperes
10 A.M.
10.30 A.M.
11 A.M.
11.30 A.M.
Full Scale=50 Amperes

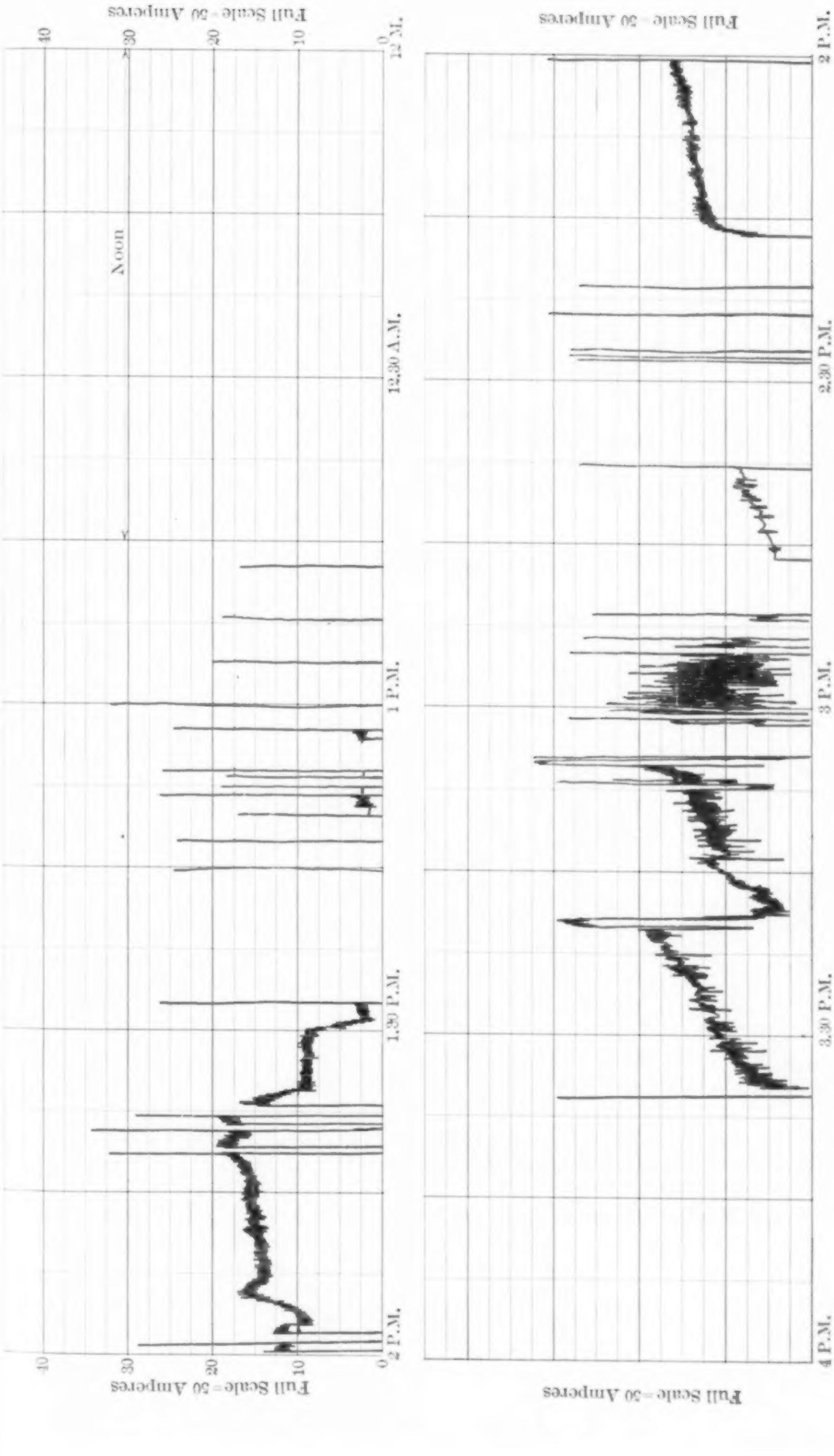


Fig. 2 Complete Meter Record for One Day from 72-in. Boring Mill

TABLE 2 ANALYSIS OF A COUNTERBORING OPERATION

	Number of Hole						Total Time To Drill	Adjustment	Change	Complete
	1	2	3	4	5	6				
Min.	7.3	7.5	7.4	7.5	7.4	7.5	44.6	19.6	8.2	72.4
% of Total							61.5	27.2	11.3	100
Min.	7.1	7.4	7.3	7.4	7.4	7.4	44	17.7	8.4	70.1
% of Total							62.8	25.2	12.0	100
Min	7.5	7.5	7.5	7.3	7.4	7.5	44.7	15.5	9.9	70.1
% of Total							64	22	14	100
Min	7.3	7.1	6.8	7.0	7.1	7.5	42.8	24.2	7.5	74.5
% of Total							57.5	32.5	10	100

No. load of drill, 1.75 kw. Power to drill, 1.75 kw. Average running load, 2.8 kw.

TABLE 3 ANALYSIS OF DRILLING AND TAPPING OPERATION
Set up equals 56 Min.

Pole No.	Operation	Time Required, Minutes Hole No.						Total Time Required			
		1	2	3	4	5	6	To Drill	To Adjust Drill	To Change Drill	Complete
1	$1\frac{9}{16}$-in. drill	1.1	1.3	1.1	1.3	1.3	1.3	7.4	5.6	....	13
	$1\frac{9}{32}$-in. drill	4.5	4.2	4.4	4.3	4.2	6.6	28.2	6.0	8.3	42.5
	$1\frac{5}{16}$-in. tap	0.9	0.6	0.7	0.7	0.5	0.8	4.2	13.2	6.6	24
							Total min.	39.8	24.8	14.9	79.5
							% of total	50	31.2	18 8	100
Turn Over = 26.2 min. delay for drawing = 31.4 min.; other delay = 57											
2	$1\frac{9}{16}$-in. drill	1.4	1.3	1.3	1.1	1.2	1.1	7.4	6.3	....	.....
	$1\frac{9}{32}$-in. drill	5.0	4.8	4.8	4.6	4.9	4.6	28.7	8.2	....	.....
	$1\frac{5}{16}$-in. tap	0.9	1.1	1.1	1.1	1.1	1.1	6.4	30.5	12.5	100
							Total, min.	42.5	45.0	12.5	100
							% of total	42.5	45.0	12.5	100
Turn Over = 21.2											
3	$1\frac{9}{16}$-in. drill	1.7.	1.3	1.5	1.2	1.5	1.2	8 4	4.4	....	.....
	$1\frac{9}{32}$-in. drill	4.9	5.1	5.6	5.4	5.4	4 7	31.1	......	3.8	.....
	$1\frac{5}{16}$-in. tap	0 6	0.8	0.6	0.8	0 8	0.6	4.2	14.3	8.4	.....
							Total min.	34.7	18.7	12.2	65.6
							% of total	53	28	19	100

DRILLING AND TAPPING

6 Table 3 is from a record made while an 8-pole revolving field was drilled and tapped for fitting pole shoes. To place the job in position required 56 min., owing to lack of prompt crane service. No lining up was required; the work was simply set upon the bed plate of the radial drill.

7 The total time consumed in adjusting the drill to proper position per pole was 5.6 min. The $1\frac{9}{16}$-in. holes were first drilled $\frac{3}{8}$-in. deep, requiring about 1.2 min. each, a total time for drilling the six holes of 7.4 min. The $1\frac{9}{16}$-in. drill was then removed and replaced by a $1\frac{9}{32}$-in. drill, requiring about 8 min. To drill each $1\frac{9}{32}$-in. hole $2\frac{1}{2}$ in. deep took about $4\frac{1}{2}$ min., or 28 min. for the six holes. Adjustments of the drill took 6 min., making a total time of $42\frac{1}{2}$ min. to complete drilling the six $1\frac{9}{32}$-in. holes. The drill was then removed and a $\frac{5}{16}$-in. tap substituted, this change requiring 6.5 min. To tap each hole took from 0.6 to 0.9 min., making a total of 4.2 min. for the six holes. The time taken for adjustments was 13.2 min., making a total of 24 min. for the tapping operation. The actual cutting time for tapping was $17\frac{1}{2}$% of the total time. The total cutting time per pole, including one tapping and two drilling operations, was 50% of the total completing time, 31.2% of the time being consumed in adjusting, and 18.8 % in changing drills for taps. About 20 to 30 min. were consumed in waiting for a crane to turn over the job in order to drill the next pole piece. The time required to complete the job can be analyzed as follows:

Set up and wait for crane	56 min.
Complete poles	560 min.
Turn over (crane service)	240 min.
Total	856 min., or 14 hr. 16 min.
Total cutting time	320 min., or 5 hr. 20 min.
Time factor	38%

RECORDS FROM 5-FT. RADIAL DRILL

8 The following results were obtained by taking records on a 5-ft. radial drill driven by a $7\frac{1}{2}$-h.p. adjustable-speed motor, with rated speeds ranging from 400 to 1600 r.p.m., while drilling a series of holes in a large steel casting. Out of $11\frac{1}{2}$ hr., 4 hr. 42 min. were consumed in actual drilling, the other 6 hr. 48 min. being required to make adjustments. In this case, the time factor was 41%. The average running load while drilling was 1.5 kw., making an average daily load of 0.7 kw., or a load factor of 10%.

9 While drilling a series of 22 holes, 67.5% of the time was consumed in actual drilling, the remaining 32.5% being consumed in moving the drill from one position to the next. In another case where holes were to be drilled and tapped, 74.5% of the time was consumed in actual drilling; while in tapping the holes, the machine was in use 44% of the time, the remainder being consumed in making adjustments. Records taken while a series of small jobs were drilled show that the time factor was as low as 20%, much time being lost in obtaining drawings and auxiliary materials.

PORTABLE MILLING MACHINE

10 On a portable milling machine driven by an induction motor of 3 h.p., 720 r.p.m., while milling slots and dovetails in an iron casting, the average running load was 1.5 kw. to 2 kw., giving a load factor of from 50 to 67%. The time factor was 54%. 24% of the total time was required to make adjustments of the cutting tool; the remaining 22% was required to set up the job, that is, to place the portable machine in a central position upon a table inside the circular casting where the machine could be completely revolved and clear the inside of the frame.

PORTABLE SLOTTER

11 On a portable slotter driven by a 10-h.p., 720-r.p.m. motor while cutting slots in a cast-iron frame, the arm carrying the cutting tool is moved up and down by reduction gearing and a rack. The cut is taken on the up-stroke. The record (not printed) shows that the peak load occurs just before the cut is taken, i.e., when the arm is reversed for the upward motion; the minimum load occurs on the downward stroke. The record also shows a variation in the amount of power required to produce the cut. This variation is due to irregularities in the feeding mechanism on the machine tested, a ratchet which had become worn. The time factor was 50% and the load factor 12%.

COMPARISON OF MILLING AND SLOTTING

12 From the results obtained an interesting comparison can be drawn between the time required to cut slots with a miller and with a slotter, as shown in the following table:

	Size of Slots Inches	Cutting Time Minutes	Minutes to Cut 1 In.
Miller	$7\frac{1}{8} \times \frac{5}{8} \times 12\frac{1}{2}$	11.8	0.95
Slotter	$7\frac{1}{8} \times \frac{5}{8} \times 15\frac{3}{4}$	8.4	0.53

13 The results show that the actual cutting time per inch of the slotter is but 56 %of the time of the miller; both were removimg exactly the same amount of material. The curves also show that the intervals required for adjustment of the positions of the tools from one slot to another averaged 6.1 min. on the miller and 3.1 min. on the slotter, an advantage of 50% again in favor of the slotter. The time to set up the work must be included in order to determine the relative advantage of one machine over the other. The setting-up time was found to depend more upon the work than upon the tool, and neither tool had an advantage. Two hours were required to set up the job on each tool. The results may then be summarized by comparing the operations of the machines in cutting two similar jobs of 12 slots 10 in. long:

	Setting up Time	Adjustments	Cutting Slots	Total
Miller	2 hr.	1 hr. 12 min.	1 hr. 44 min.	4 hr. 56 min.
Slotter	2 hr.	0 hr. 36 min.	1 hr. 04 min.	3 hr. 40 min.

14 This shows that the total time required by the slotter was but 74% of that required by the miller; a saving of 1 hr. 16 min. on every such job.

POWER REQUIRED TO OPERATE PLANERS

15 Table 4 contains a summary of results to determine the power required to operate various motor-driven planers. The average time factor in ordinary planing operations is about 50 to 60%.

CURVES FROM MACHINES IN A STEEL TUBE MILL

16 Fig. 3 shows a curve taken from a motor operating welding rolls while lap welding 5-in. tubes. The rolls were driven by a 150-h.p. induction motor.

TABLE 4 ANALYSIS OF POWER REQUIRED TO OPERATE PLANERS

Size Planer	H. P. of Motor	Reversal				Cutting Stroke		Reverse Stroke		No Load	Average Running Load		Load Factor at 50% Time Factor
		a		b									
		Kw.	% Full Load	Kw.	% Full Load	Kw.	% Full Load	Kw.	% Full Load		Kw.	% Full Load	
56 in. x 12 ft.	15	8.5	56	6.5	43	2.5-5	17-34	3	20	2	4-5	30	15
7 ft. x 12 ft.	15	6	40	3	20	1-2	7-14	0.75	5	0.6	4	25	12.5
14 ft. x 20 ft.	30	34	113	30	110	6-19	20-34	8	27	5.5	11	35	17
10 ft. x 20 ft.	50	22	45	16	30	12-16	25-32	7	14	4.5	16	30	15
14 ft. x 30 ft.	40	40	115	24	60	10-16	25-40	10	25	5	15	36	18

Reversal *a*, from cutting to return stroke.
Reversal *b*, from return to cutting stroke.

To reduce the peak load thrown on the motor, the rolls were equipped with a 5-ft. diameter, 5000-lb. fly wheel. This record is interesting, in that it shows that a friction load of 12 kw. was required about 91% of the time, under which condition of operation the motor, on account of its light load, was operating at a power factor of about 30%, which is an undesirable condition for the power plant.

17 The duration of peak load is in each instance about eight seconds, which amounts to only about 9% of the total cycle of operation. During this period the input to the motor was from 128 to 160 kw. A study of the records shows that a smaller motor should be installed. The motor should be designed with a larger slip, or drop in speed between no load and full load, so that with a some-

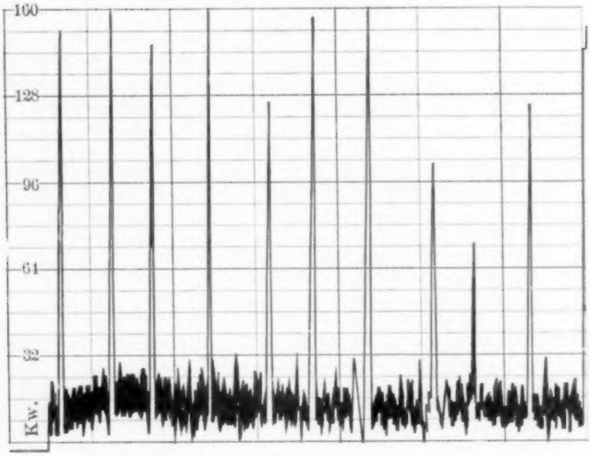


FIG. 3 RECORD FROM WELDING ROLLS EQUIPPED WITH FLYWHEEL

what larger flywheel, when the load is steadily thrown on the motor, it would slow down, allowing the fly wheel to give forth energy and in this way moving out or lowering the peaks for instantaneous demand for current from the line. With a smaller motor the power factor would be increased, the efficiency improved, and the load factor also improved. At the time the tests were made a meter was used, having a paper speed of 24 in. per hr. The record shows that tubes were rolled at the rate of 40 per hour.

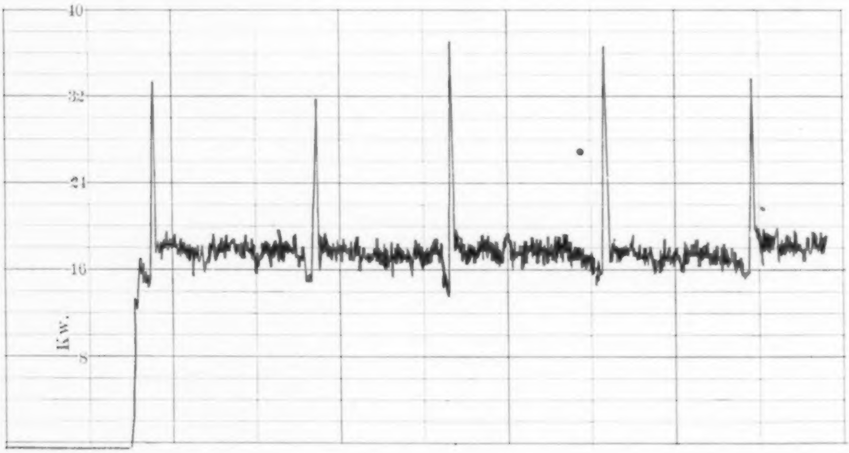


FIG. 4 RECORD FROM HOT-ROLL SCARFER

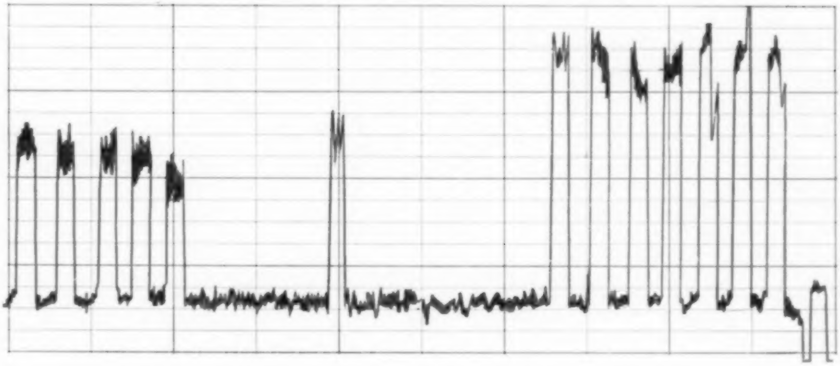


FIG. 5 RECORD FROM SHEAR SCARFER

18 The curve represented by Fig. 4 was taken from a 75-h.p. motor, operating a hot-roll scarfer, scarfing sheets for 12-in. lap-welded tubes. It shows that the friction load of 18 kw. is practically constant for about 90 % of the time, and that the maximum or peak load of about 34 kw. occurred for about 4% of the total time. At the time these records were taken the meter was operating at a speed of 24 in. per hr., and the rolls turning out 10 and 15 tubes per hour. The difference in peak load is due to the fact that an increase in width of the metal causes a slight increase in power. Undoubtedly a 50-h.p. motor would have been satisfactory for this work with much more economy than the installed motor.

19 The curve represented by Fig. 5 is a record showing the operating conditions of a 50-h.p. induction motor driving a shear scarfer. On this curve the

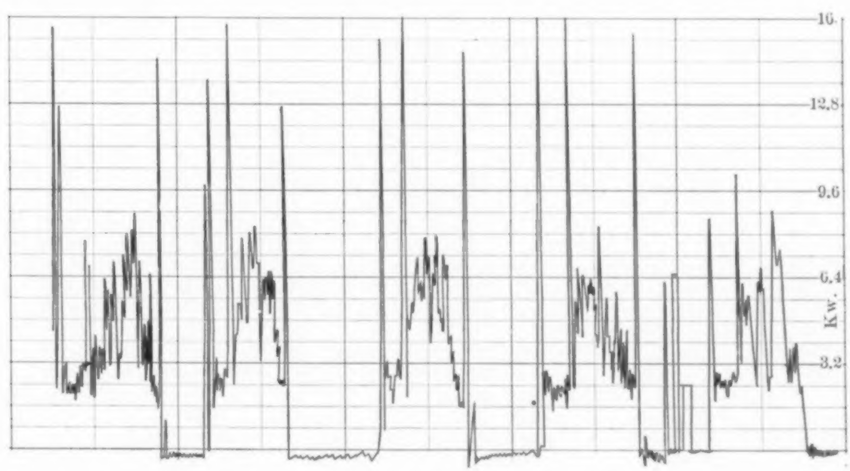


FIG. 6 RECORD FROM PIPE CUTTING-OFF MACHINE

friction load was shown at about 2.3 kw., of a duration of 55% of the time. The peak loads require from 10 to 13 kw. for the balance, or 45% of the time. As the duration of the peak is only about 34 seconds, a smaller motor of about 25 h.p. would be of sufficient capacity to do the work. In this instance, as in the others, a meter having a 24-in. movement of the record was used.

PIPE CUTTING-OFF MACHINE

20 The record shown in Fig. 5 was taken from a 5-h.p. motor operating a pipe cutting-off machine, cutting 18-in. tubes at an average cutting speed of about 38 ft. per min. It will be noted that about 16 kw. were required for starting, while the average load during cutting was about 6 kw. The motor was reversed for the reaming operation, and the peak was very large, going off the scale. To start the machine the motor was again reversed, such manipulation causing very severe overloads on the motor and the gearing to the machine. For a reversing operation of this nature an induction motor having a large slip would be desirable, or a slip-ring type of motor, thus reducing the demand upon the line. A direct-current motor, if used, should be supplied with very heavy compound winding.

APPENDIX NO. 2. POWER REQUIRED TO REMOVE METAL

1 The power required to remove metal depends upon the nature of the cutting tool and the amount of metal removed per minute. Cutting tools may be divided into three general classes: (*a*) lathe tool type; (*b*) drills; (*c*) milling cutters.

LATHE TOOL TYPE

2 The lathe tool is used on lathes, boring mills, planers, shapers and slotters. Tests show that the power required by a tool of this kind when removing metal depends upon the cutting angle of the tool and the number of cubic inches of metal removed per minute. From observation and data

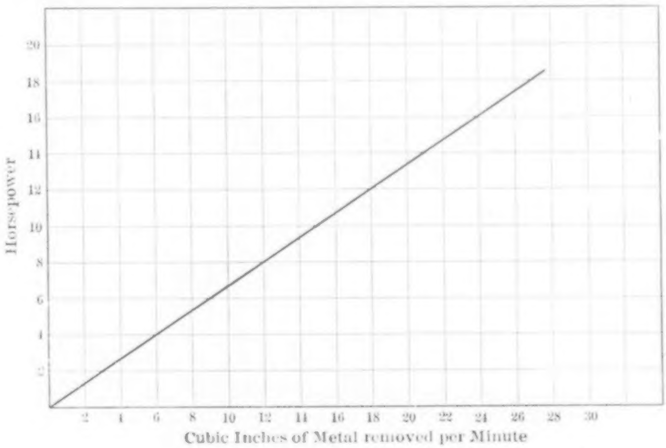


FIG. 1 RELATION BETWEEN HORSEPOWER AND CUBIC INCHES METAL REMOVED; MILD STEEL, 0.40% CARBON

obtained by means of the graphic recording meter, and the use of tools having a cutting angle of about 75 deg. to 80 deg. the curve shown in Fig. 1 was obtained. The results were independent of the cutting speed, feed and depth of cut, and show that a definite relation exists between the horsepower required to remove metal and the number of cubic inches removed per minute. The cubic inches of metal removed per minute were found to be as follows:

(*a*) area of cut (sq. in.) $\times$ cutting speed (ft. per min.) $\times$ 12

(*b*) area of cut (sq. in.) = depth of cut (in.) $\times$ feed (in. per revolution)

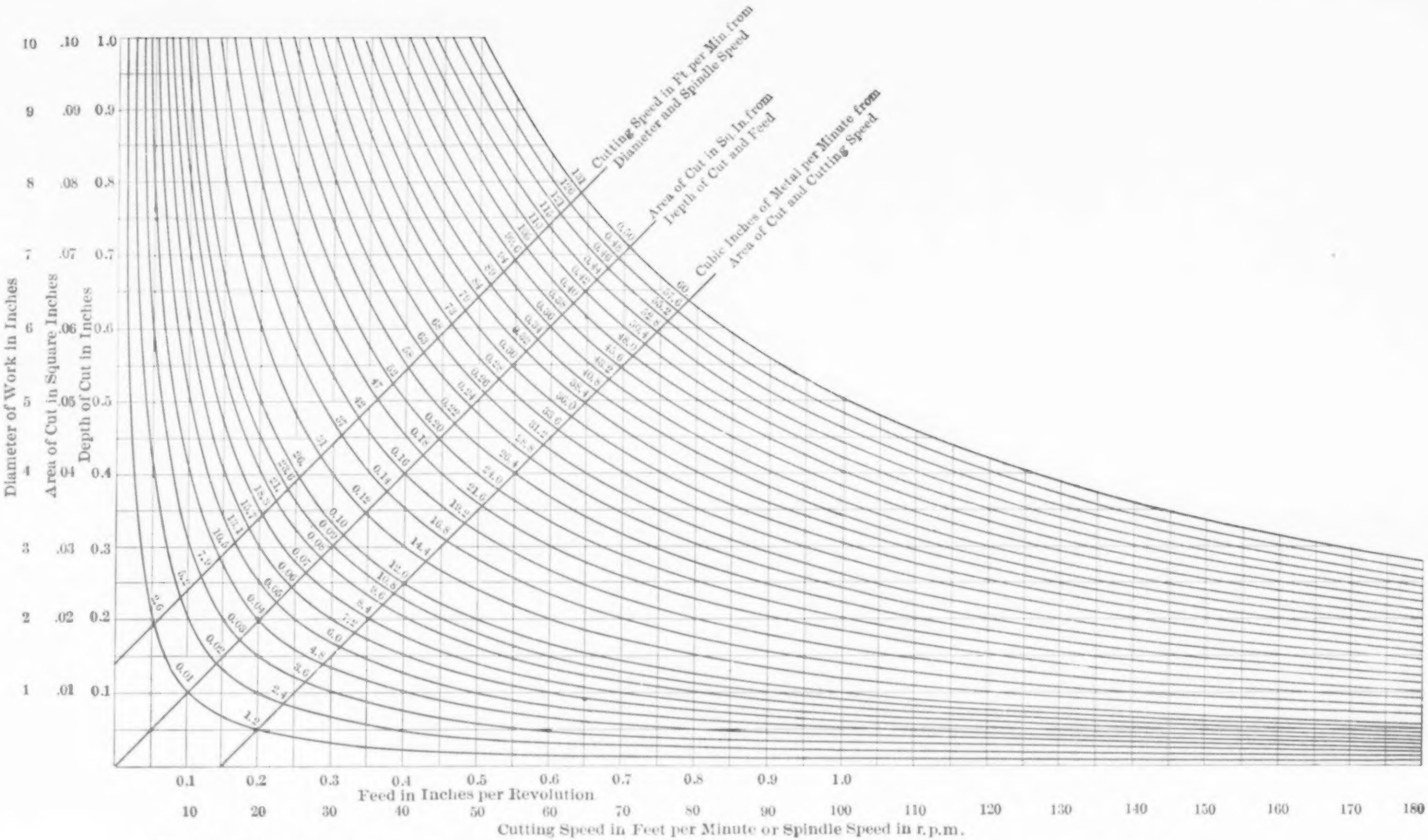


PLATE 1 MACHINE TOOL CALCULATOR FOR LATHES, PLANERS, SHAPERS, SLOTTERS AND BORING MILLS

DIRECTIONS FOR USING PLATE 1

a To find cutting speed: From intersection of horizontal line corresponding to diameter and vertical line corresponding to spindle speed, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find area of cut: From intersection of horizontal line corresponding to depth of cut and vertical line corresponding to feed, follow nearest curve and use value found in oblique line of figures marked area of cut.

c To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of cut and vertical line corresponding to cutting speed follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

To use curve, knowing diameter of work, spindle speed, depth of cut and feed, find cutting speed from (*a*) area of cut from (*b*) and cubic inches of metal removed per minute from (*c*).

3 The horsepower required to remove metal with the tools ordinarily employed can be expressed by:

$$\text{h. p.} = \text{a constant} \times \text{cu. in. removed per min.}$$

The constant varies with the kind of metal removed.

4 In order to estimate the amount of power required to remove a given amount of metal per minute the graphic method shown in Plate 1 has been designed. This diagram is a multiplication table; those familiar with analytical geometry will recognize the equilateral hyperbola whose equation, referred to its asymptotes, is xy = constant.

5 To determine the cutting speed the usual procedure is as follows:

$$\text{cutting speed (ft. per min.)} = \frac{\pi \times \text{diameter} \times \text{r.p.m.}}{12}$$
$$= \text{constant} \times \text{diameter} \times \text{r.p.m.}$$

In the diagram each hyperbola corresponds to a given cutting speed. The coördinates of all diameters and spindle speeds producing the same speed intersect on the same hyperbola. The cutting speed corresponding to any diameter, rotation at any number of r.p.m., is found indicated on the hyperbola passing through the intersection of the coördinates corresponding to the given values of diameter and r.p.m.

6 In a similiar manner an area corresponding to any depth of cut in inches and feed in inches is obtained, and also the cubic inches of metal removed per minute can be determined from the area of cut and the cutting speed. The directions for using the diagram are given in connection with it.

7 With the cutting tools ordinarily employed the following values have been found by tests to exist for the horsepower required to remove 1 cu. in. of the following metals, per min.:

Brass and similar alloys	0.2 to 0.3
Cast iron	0.3. to 0.5
Wrought iron	0.6
Mild steel (0.30%–0.40% carbon)	0.6
Hard steel (0.50% carbon)	1.00 to 1.25
Very hard tire steel	1.50

8 It must be remembered that these constants represent general average conditions; considerable variation may occur where special cutting tools are used and special grades of metal are encountered.

LATHES

9 The following examples will explain the application of the diagram, Plate 1, to lathe work.

Example:	Diameter of work	= 5.5 in.
	Spindle speed	= 45 r.p.m.
	Depth of cut	= 0.45 in.
	Feed per revolution	= 0.06 in.

10 Find the intersection of the horizontal line through 5.5 in. diameter of work, and the vertical line through 45 r. p. m. spindle speed. The curves pas-

sing nearest this intersection correspond to a cutting speed of 63 and 68 ft. per min., indicating by interpolation a cutting speed in this case of 65 ft. per min. The area of cut, with depth of cut 0.45 in. and feed 0.06 in. is 0.027 sq in. The cubic inches of metal removed per minute, corresponding to an area of cut 0.027 sq. in. and a cutting speed of 65 ft. per min., is determined by finding the intersection of the horizontal line passing through 0.027 sq. in. area of cut and 65 ft. per min. This intersection is between the curves corresponding to 19.2 and 21.6 cu. in., showing that about 20 cu. in. of metal are removed per min. If the metal removed is wrought iron, the horsepower required is $0.6 \times 20 = 12$ h.p. If 0.50% carbon steel is turned, $1.00 \times 20 = 20$ h.p., is required. Brass would require $0.25 \times 20 = 5$ h.p.

BORING MILL

Example:	Diameter of work	=45 in.
	Speed of table	= 4.5 r.p.m.
	Depth of cut	= 0.25 in.
	Feed	=0.10 in. per revolution

11 The diameter of work goes only to 10 in. in the vertical column of the diagram. These may be multiplied by 10, and if used with the spindle speeds as they stand, the results in the oblique column of cutting speeds must be multiplied by 10. In case of large diameters the spindle or table speeds are usually low. The simplest way to use the diagram in these cases is to interchange *diameter of work and spindle speed,* i. e., assume that the diameter of the work is 10, 20, 30, etc., in the horizontal column, and the table speed under 1, 2, 3, etc., in the vertical column. In the problem under consideration the cutting speed is as follows:

12 The intersection of the horizontal line through 4.5 and the vertical line through 45 correspond to a cutting speed of 52 ft. per min. The area of cut is 0.025 sq. in. The intersection of the horizontal line through 0.025 sq. in. area of cut, and the vertical line through 52 ft. per min. cutting speed lies between curves representing 14.4 and 16.8 cu. in., indicating that 15 cu. in. are removed per min. If cast iron of a soft quality is removed the power required for cutting will be $15 \times 0.3 = 4.5$ h. p. If the cast iron is of hard quality, $0.5 \times 15 = 7.5$ h. p., will be required.

SHAPER OR PLANER

Example:	Depth of cut	= 0.75 in.
	Feed per stroke	= $\frac{1}{16}$ in.
	Cutting speed	= 45 ft. per min. (from characteristic of planer or shaper)

Area of cut $0.75 \times \frac{1}{16} = 0.046$ sq. in.

13 The cubic inches of metal removed per minute, corresponding to an area of cut of 0.046 sq. in., and a cutting speed of 45 ft. per min., is 24. The power required for cutting in the machine a hard grade of cast iron will under these conditions be $24 \times 0.5 = 12$ h. p.

14 In a planer the power required for reversing is usually considerably more than that required to cut metal, depending upon the design of the reversing

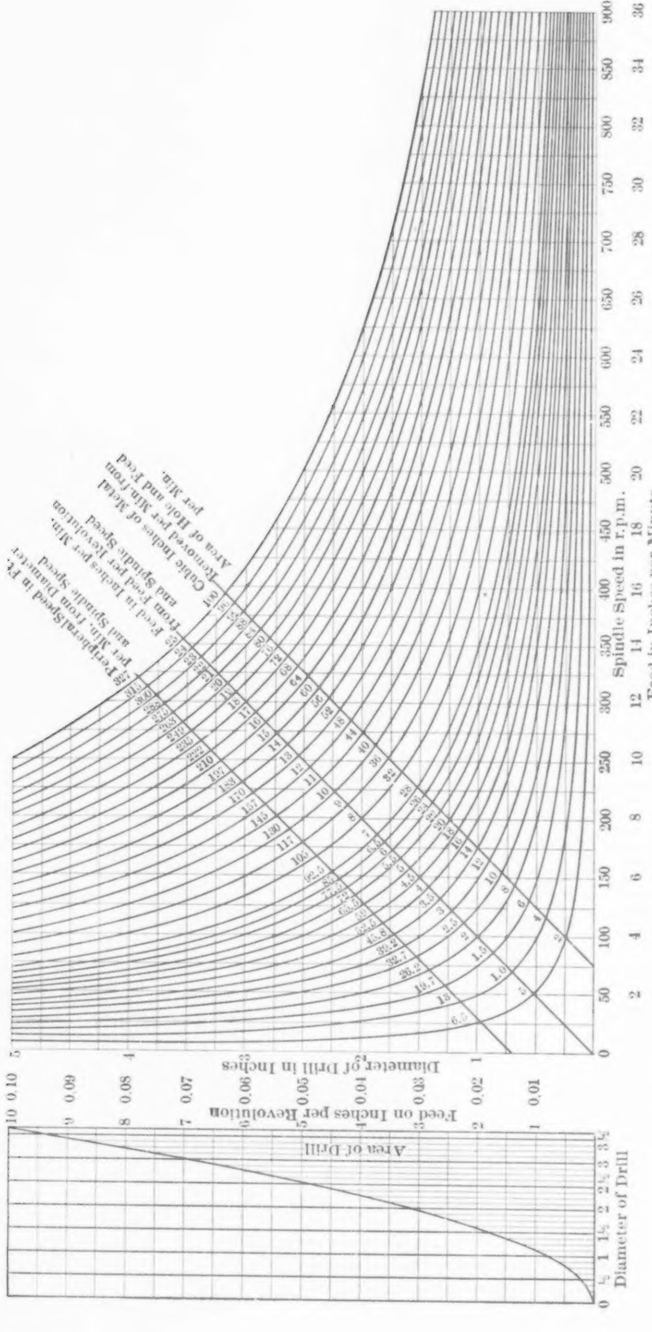


PLATE 2 MACHINE TOOL CALCULATOR FOR DRILLS

DIRECTIONS FOR USING PLATE 2

a To find cutting speed: From intersection of horizontal line corresponding to diameter of drill and vertical line corresponding to spindle speed, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find feed in inches per minute from feed per revolution and spindle speed: From intersection of horizontal line corresponding to feed in inches per revolution and vertical line corresponding to spindle speed follow nearest curve and use value found in oblique line of figures marked feed in inches per minute.

c To find area of drill from diameter of drill use curve on left side of figure: Find intersection of vertical line corresponding to diameter of drill with the curve follow the horizontal line passing through this intersection and obtain area under area of drill in vertical column.

d To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of drill and vertical line corresponding to feed per minute follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

Knowing diameter of drill, spindle speed and feed per revolution, find cutting speed from (*a*), and cu. in. metal removed per minute from (*b*), (*c*), and (*d*).

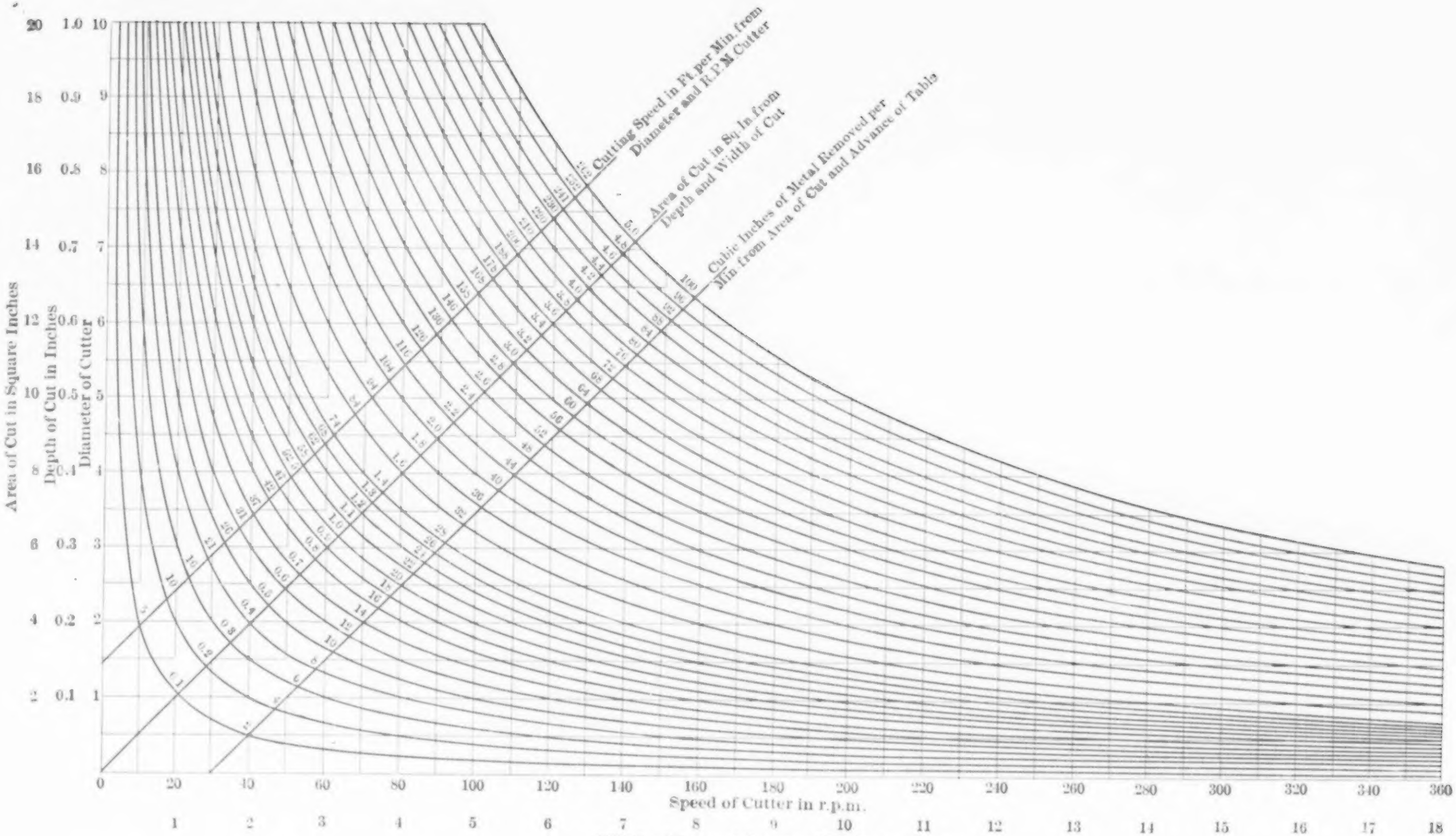


PLATE 3 MACHINE TOOL CALCULATOR FOR MILLING MACHINES

DIRECTIONS FOR USING PLATE 3

a To find cutting speed: From intersection of horizontal line corresponding to diameter and vertical line corresponding to spindle speed of cutter, follow nearest curve and use value found in oblique line of figures marked cutting speed.

b To find area of cut: From intersection of horizontal line corresponding to depth of cut and vertical line corresponding to width of cut, follow nearest curve and use value found in oblique line of figures marked area of cut.

c To find cubic inches of metal removed per minute: From intersection of horizontal line corresponding to area of cut and vertical line corresponding to advance of table per minute, follow nearest curve and use value found in oblique line of figures marked cubic inches of metal removed per minute.

To use curve, knowing the diameter of cutter, spindle speed, depth of cut, width of cut, and advance of table per minute, find cutting speed from (*a*), area of cut from (*b*), cubic inches metal removed per minute from (*c*).

mechanism, the flywheel effect and the speed characteristic of the motor. In a shaper the power required to reverse is not very great, and is usually less than the power required for cutting.

SLOTTER

15 In most cases the cutting tool is fed inwardly on this type of machine; the following example shows how the diagram is used to determine the rate of removing metal. With other methods of feeding the tool the diagram is used in the same way as in the case of a planer or a shaper.

Example: Width of tool and cut = 0.5
Feed per stroke = 0.06
Cutting speed = 35 ft. per min.
Area of cut 0.5 x 0.06 = 0.03 sq. in.

16 The cubic inches of metal removed per minute from the intersection of the horizontal and vertical line through 0.03 sq. in. and 35 ft. per min. are 13. In the case of mild steel the horsepower required would be 13 x 0.6 = 7.8 h. p.

DRILLS

17 The power required in drilling operations can also be expressed as a constant times the cubic inches of metal removed per minute. The conditions are, however, more complicated than in the lathe tool, since the friction of the drill and the chips on the sides of the hole increase the power requirement as the drill enters the metal. This is especially true when cast iron is drilled, as chips have a jamming action. The variable cutting speed at the cutting edge of the drill, from zero at the center to the peripheral speed of the drill, also causes a jamming action and tends to increase the power per cubic inch per minute over that required to remove the same amount of metal by means of the lathe tool type. With drills generally employed, the value per horse power per cubic inch of metal removed per minute. is about double that required by ordinary lathe tools.

18 Plate 2 is a diagram with full instructions for determining the cubic inches of metal removed with drills. The constants for determining the power required are about double those for lathe tools.

Example: Size of drill = 2 in. diameter
Feed per minute = 2.5 in.
Speed of drill = 150 r.p.m.
Metal drilled: cast iron.

19 The peripheral or maximum cutting speed of the drill is found as follows (Rule *a*, Plate 2): The horizontal line corresponding to a diameter of 2 in. intersects the vertical line corresponding to 150 r.p.m. on the curve corresponding to a cutting speed of 77.5 ft. per min. The area of the 2 in. drill (rule *c*) is 3 sq. in. This area at a feed of 2.5 in. per min. corresponds to removing 7 cu. in. per min. (rule *d*). For cast iron the horsepower per cu. in. per min. is about 0.8, twice that for lathe tools, hence the power required to drive the drill in this case is $0.8 \times 7 = 5.6$ h.p., which agrees closely with an actual test. For

mild steel the power required is $1.2 \times 7 = 8.4$ h.p. In drilling a hole of this size the friction of the chips does not increase the power materially as the depth of the hole increases, since there is sufficient space for the drill to free itself of chips.

MILLING CUTTERS

20 Plate 3 is a diagram with full instructions for determining the amount of metal removed per minute by a milling machine.

Example:	Width of cut	= 8 in.
	Depth of cut	= 0.2 in.
	Advance of table per min.	= 5 in.
	Area of cut is 8×0.2	= 0.16 sq. in.

21 To find the cubic inches of metal removed per minute, find on the diagram the intersection of the horizontal line through 0.16 sq. in., and a vertical line corresponding to a table advance of 5 in. per min. The curve passing through this intersection corresponds to a rate of cutting of 16 cu. in. of metal per min. For machinery steel or mild steel, the power required by a horizontal milling machine of this type is about 1.6 per cu. in. per min, making the total requirement $1.6 \times 16 = 25.6$ h.p. A vertical miller requires about 1 h.p. per cu. in. per min., or 16 h.p. under the foregoing conditions.

22 The power required by milling cutters varies according to their construction, and care should be employed to determine the proper constant for each class of cutters. By means of tests made with the graphic meter on motor-driven tools the proper constant can easily be determined in any given case.

APPENDIX NO. 3. SIZES OF MOTORS RECOMMENDED TO DRIVE MACHINE TOOLS

The accompanying tables contain the sizes and speeds of motors usually employed with the average duty indicated for machine tools. The constant speed motors are selected with a view to utilizing speeds as near as possible to those obtainable with 60-cycle induction motors. By this means the same gear ratios can be employed with either direct current motors or 60 cycle induction motors.

2 The average load factor for motors driving lathes is from 10 to 25 %. On some special machines, as driving wheel and car wheel lathes, the cuts are all heavy, which increases the average load factor to from 30 to 40%.

3 For extension boring mills, 5 h.p. motors are used to move the housings on from 10 ft. to 16 ft. mills, 7½ h.p. for from 14 ft. to 20 ft. mills and 10 h.p. for from 16 ft. to 24 ft. mills. The load factor of the driving motor on boring mills averages fom 10 to 25 %.

4 The load factor of motor-driven drills is about 40%, when the larger drills applicable thereto are used. If the smaller drills are used the load factor averages 25% and lower.

5 For the average milling operations the load factor averages from 10 to 25 %. On slab milling machines where large quantities of metal are renewed it will average from 30 to 40%.

6 The work on this class of machinery is usually light and much time is required in making adjustments. Hence the load factor is rarely higher than 20%.

7 On planers the load factor averages between 15 and 20%. The motor must be large enough to reverse the bed quickly, yet this peak load occurs for such short intervals that it does not increase the average load per cycle very much.

8 The work done on shapers is of a varying character. With light work the load factor will not exceed from 15 to 20%; with heavy work, the load factor will be as high as 40%.

9 The conditions encountered on slotters are similar to those on shapers.

TABLE 1 SIZES AND SPEEDS OF MOTORS ON LATHES

ENGINE LATHES

Adjustable speed, ratio 1 : 3.

Swing In.	Light Duty			Medium Duty			Heavy Duty		
	h.p.	Adjst. Speed	Const. Speed r.p.m.	h.p.	Adjst. Speed	Const. Speed r.p.m.	h.p.	Adjst. Speed	Const. Speed r.p.m.
14	2	Ratio	1800	3	Ratio	1800	5	Ratio	1200
16	3	1 : 3	1800	5	1 : 3	1200	5	1 : 3	1200
18–20	3		1800	5		1200	7 : 5		1200
22–24	5		1200	7 : 5		1200	10		1200
27–30	7½		1200	10		1200	15		1200
36–48	7½		1200	10		1200	20		900

SPECIAL LATHES

Type	h.p.	Adjustable Speed
Car wheel 48 in.	20	1 : 3
Double axle, moderate duty	15	1 : 3
Heavy duty	25	1 : 3

DRIVING WHEEL LATHES

Size, in.	h.p.	Adjustable speed
51	15	Ratio 1 : 3
60–69	20	
79	25	1200 r.p.m.
84	25	
90	30	
100	50 5 tail stock	

TABLE 2 SIZES AND SPEEDS OF MOTORS

VERTICAL BORING MILLS

Size, in.	h.p.	Adjustable Speed	Constant Speed
24-30 in.	5	Ratio 1 : 3	1200
36-42 in.	$7\frac{1}{2}$		1200
60-90 in.	10		1200
	5-rail		
100 in.	15		1200
	5 -rail		
10 ft.	20		900
	$7\frac{1}{2}$-rail		
12 ft.	20		900
	$7\frac{1}{2}$-rail		
14 ft.	25		900
	$7\frac{1}{2}$-rail		
16 ft.	30		900
	10-rail		

TABLE 3 SIZES AND SPEEDS OF MOTORS ON DRILLS

RADIAL DRILLS

Size, ft.	h.p.	Adjustable speed	Constant Speed
4	3	Ratio 1 : 3	1800
5	5		1200
6	5		1200
10	$7\frac{1}{2}$		1200

UPRIGHT DRILLS

Size, in.	h.p.	Adjustable Speed	Constant Speed r.p.m.
Friction	$\frac{1}{4}$	Ratio 1 : 3	1800
15	$\frac{1}{2}$		1800
20-26	1		1800 / 1200
28-34	2		1800 / 1200
42-50	3		1800 / 1200

MULTIPLE-SPINDLE DRILLS

Size, in.	h.p.	Adjustable Speed	Constant Speed
4-2	$7\frac{1}{2}$	Ratio 1 : 3	1200
6-2	10		1200
8-2	10		1200

TABLE 4 SIZES AND SPEEDS OF MOTORS ON MILLING MACHINES

HORIZONTAL—PLAIN OR UNIVERSAL

Table Feed In.	Cross Feed In.	Vertical Feed In.	h.p. Mod. Heavy	Adjustable Speed	Constant Speed r.p.m.
24	8	18	3	Ratio 1 : 3	1800
30	10	18	5– 7½		1200
36	12	20	7½–10		1200
50	12	20	10–15		....

VERTICAL MILLING MACHINES

Table Diameter In.	Spindle Diameter In.	h.p.	Adjustable Speed	Constant Speed r.p.m.
28	4	5	Ratio 1 : 3	1200
32	4	7½		1200
40	4½	10		1200
54	5	15		1200
70	6	20		900

SLAB MILLING MACHINES

Width of Table, In.	h.p.	Adjustable Speed	Constant Speed r.p.m.
24–30	10	Ratio 1 : 3	1200
36	15		1200
60	25		900
36 heavy	25		900
42 heavy	50		900

TABLE 5 SIZES AND SPEEDS OF MOTORS

HORIZONTAL BORING, DRILLING AND MILLING MACHINES

Spindle, In.	h.p.	Adjustable Speed	Constant Speed r.p.m.
3½	3	Ratio 1 : 3	1800
4	5		1200
5	7½		1200
6	10		1200
7	15		1200

TABLE 6 SIZES AND SPEEDS OF MOTORS ON PLANERS

Medium Duty			Heavy Duty		
Size, in.	h.p.	Constant Speed r.p.m.	Size, in.	h.p.	Constant Speed r.p.m.
24 x 24	5	900	24 x 24	7½	900
30 x 30	7½	900	42 x 42	25	900
36 x 36	10	900	56 x 56	25	900
48 x 48	15	900	Frog and	30	900
56 x 56	15	900	Switch Forge	...	...
			12 x 10 ft.	60	720
			14 x 12 ft.	10 (rail)	...
				75	...
				12 (rail)	720

TABLE 7 SIZES AND SPEED OF MOTORS ON SHAPERS

Size In.	h. p.	Adjustable Speed	Constant Speed r. p. m.
14–20	3	Ratio 1:3	1800
24	5		1200
36	7½		1200

TABLE 8 SIZE AND SPEEDS OF MOTORS ON CRANK SLOTTERS

LIGHT, MEDIUM AND HEAVY

Size In.	h. p.	Medium	Adjustable Speed	Constant Speed r. p. m.
10	3	5	Ratio 1:3	1800
10–16	5	7½		1200
20	7½	10		1200
26–30	15	..		1200
GEARED SLOTTERS				
24–60	20	....	1:3	900

TABLE 9 SIZES AND SPEEDS OF MOTORS ON COLD SAWS

Diameter In.	Thickness In.	h. p.	Adjustable Speed	Constant Speed r. p. m.
12	$\frac{5}{32}$	2	Ratio 1:3	1800
15	$\frac{5}{32}$	2		1800
18	$\frac{3}{16}$	3		1800
20	$\frac{3}{16}$	3		1800
24	$\frac{3}{16}$	5		1200
32	$\frac{3}{16}$	$7\frac{1}{2}$		1200
36	$\frac{3}{16}$	10		1200

TABLE 10 SIZES AND SPEEDS OF MOTORS ON GRINDERS

Size In.	h. p.		Constant Speed r. p. m.
	Medium	Heavy	
10x 50	5	$7\frac{1}{2}$	1200
10x 72	5	$7\frac{1}{2}$	1200
10x 96	5	$7\frac{1}{2}$	1200
10x120	5	$7\frac{1}{2}$	1200
14x 72	10	—	1200
18x120	10	15	1200
18x144	10	15	1200
18x168	10	15	1200
18x 96	10	15	1200
44-in. car wheel grinder		30	900

APPENDIX NO. 4. CONDITIONS WHEN EQUIPPING OLD MACHINES WITH MOTOR DRIVE

1 When changing over from lineshaft drive to individual motor drive the question arrises whether to equip the old lineshaft-driven machines with motors or to install new motor-driven machine tools. The old machines are not as strong in construction as new tools designed for motor drive, nor are they equipped with the latest devices by means of which the time required to make adjustments can be greatly reduced. Owing to weaker construction old machines cannot be made to remove metal as rapidly as machines built with this point in view. The old machines are also more or less worn and not as accurate as new machines. A concrete example will show a method of arriving at a decision between attaching a motor to an old machine and purchasing a complete new motor-driven equipment.

2 The case taken for consideration involves the modification or exchange of a 72-in. vertical belt-driven boring mill, so as to obtain a greater output at lower cost per unit of product. This mill, the original cost of which was \$3200, has been in use five years. The hourly overhead operating charge has been determined at 91 cents. The machinist receives 35 cents an hour for 54 hours per week (2808 hr. per year). The total earnings for the year from this machine amount to \$4200. The operating expenses for the year are as follows:

Overhead	0.91×2808 =	\$2555.28
Wages	0.35×2808 =	982.80
Total		\$3538.08
Net profit \$4200 − \$3538 =		\$662.00

3 The depreciated value of this tool on a basis of 10% reduced balance is 66% of its first cost. If a motor is installed the investment appears as follows:

Value of tool	$\$0.66 \times 3200$ =	\$2112.00
Cost of motor, gears, controller, wiring, etc.	=	550.00
Total investment		\$2662.00

4 The hourly overhead charge of 91 cents includes interest and depreciation at 16 cents an hour; the overhead change exclusive of interest and depreciation will therefore be 75 cents an hour. The depreciation on the new investment for the remaining five years' life of the tool will be 20% per year, making the

charge for interest and depreciation 26%. The operating cost of the old tool with motor drive is therefore,

Overhead (exclusive of interest and depreciation) $0.75 × 2808	= $2106.00
Interest and depreciation, 26% of $2662	= 692.12
Wages, $0.35 × 2808	= 982.80
	$3780.92

Assuming 10% increased earnings, due to adoption of individual motor drive, makes the total earnings:

$4200 + $420 = $4620.00

The net profit is then

$4620 - $3780.92 = 839.08

or 31.5% interest on the investment of $2662.

5 The corresponding figures based on the installation of a new machine tool with individual motor drive are approximately as follows:

Cost of new tool =	$3400.00
Cost of motor etc. =	270.00
	$3670.00
Scrap value of old tool at 5%	160.00
Investment	$3510.00
Overhead operating charge $0.75 × 2808 =	$2106.00
Wages as above	982.80
Interest and depreciation for 10 years (depreciation 10% interest 6%) 16% × $3510 =	561.60
Total	$3650.40

Assuming 25% increased output for the year, the total earnings become

125% × $4200	= $5250.00
Net profit is then $5250 − $3650.40	= $1599.60

or 45.3% interest on the investment.

CONCLUSIONS

6 The above figures show that for the conditions given, approximately 14% greater return on the investment is gained by installation of a complete new tool. It is evident, therefore, that although a somewhat greater capital is required for the new installation, it is by far the better investment. It is also probable that the old machine tools would not last more than five years after the changes were made, whereas the new tools will give good service for at least double that period. Furthermore, the new machine has the added advantage of being in first class condition, thus insuring greater accuracy of workmanship and less liability to accidental delays.

APPENDIX NO. 5. OVERHEAD CHARGES AND MACHINE-HOUR RATES

The following analysis outlines a method of determining the hourly overhead charges per machine tool, which will be called the *machine-hour rates*. Overhead charges can be grouped in three main classes:

A Charges against the entire factory.

a Fixed charges: these include interest and depreciation, taxes and insurance on buildings, grounds and accessories.

TABLE 1 MACHINE HOUR RATES

Type of Machine	Charges per Hour				Depreciation	Power	Total or Mch. Hr. Rate
	Fixed	Variable	Salaries	Interest			
Vertical Boring Mills.							
40-in.-60 in.	$0.02	$0.25	$0.15	$0.05	$0.05	$0.01	$0.53
72 in.-100 in.	0.04	0.45	0.25	0.08	0.08	0.01	0.91
10 ft.-14 ft.	0.05	0.80	0.40	0.15	0.15	0.02	1.57
16 ft.-24 ft. Ext.	0.08	2.00	1.00	0.30	0.30	0.03	3.71
Average per cent of total	3%	52%	28%	8%	8%	1%	100%
Radial drills, 5 ft	$0.02	$0.30	$0.20	$0.03	$0.03	$0.01	$0.59
Radial drills, 10 ft	0.04	0.60	0.35	0.09	0.09	0.01	1.18
Average Per Cent of Total	3%	51%	31%	7%	7%	1%	100%
Engine Lathes:							
30 in.-40 in.	$0.02	$0.25	$0.12	$0.04	$0.04	$0.01	$0.48
40 in.-60 in.	0.03	0.50	0.25	0.10	0.10	0.01	0.99
Average Per Cent of Total	3%	51%	25%	10%	10%	1%	100%
Planers:							
36 in.-56 in.	$0.04	$0.55	$0.30	$0.05	$0.05	$0.01	$1.00
7 ft.-10 ft.	0.06	1.10	0.60	0.15	0.15	0.02	2.08
12 ft.-14 ft.	0.15	2.60	1.40	0.25	0.25	0.03	4.68
Average Per Cent of Total	3%	55%	30%	5.5%	5.5%	1%	100%

b Variable charges: these include repairs and renewals on buildings and accessories, omitting all charges which can be set off directly to a particular section of the factory; charges against the store room and the tool room; defective design, material or workmanship; printing and stationery; lubricants and general manufacturing supplies.

c Salaries (not chargeable to a definite section): these include cost of superintendence (manager, superintendent, foreman); engineering and drawing; clerical force, including office boys and general laborers.

B Charges against each section of the factory.

a Fixed charges; including an equitable portion of the total factory fixed charge and interest, and depreciation on auxiliary apparatus located in the section (except machine tools).

b Variable charges: these include a portion of the variable charges as well as similar charges belonging to the section, such as repairs and renewals, storeroom and tool room charges, defective design, material and workmanship, lubricants and manufacuring supples.

c Salaries: including a portion of the total salaries as well as those belonging exclusively to the section, that is, foremen, clerks, errand boys, laborers. cranemen, etc.

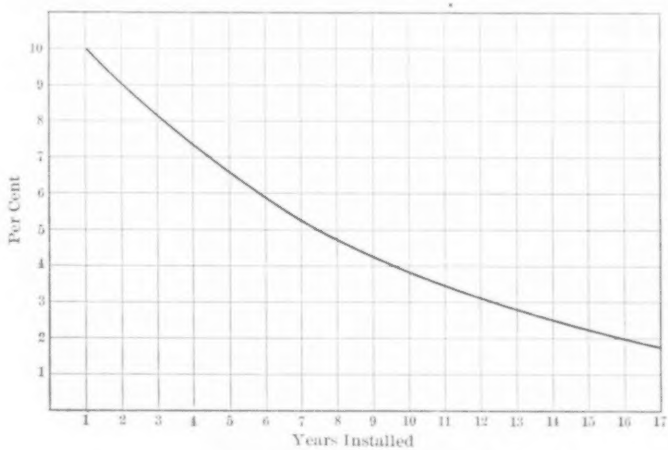


Fig. 1 Depreciation at 10%, Reducing Balance

C Charges against each machine tool.

a Portion of fixed charge.

b Portion of variable charge.

c Portion of salaries charge.

d Interest on cost of tool, fairly taken at 6%.

e Depreciation of value of tool (see explanation below).

f Cost of power to operate tool, including also lighting and crane service.

DEPRECIATION OF VALUE OF MACHINE TOOLS

2 A method frequently used in calculating the depreciation in value of a machine tool is to allow 10% of a reducing balance; that is, 10% of the first cost if charged off the first year, 10% of the remaining cost, the second year, and 10% of the second remainder the third year, etc. This method is based upon the fact that the apparatus actually decreases in value year by year. Allowance for depreciation in any given year can be made easily by the aid of the curve in Fig. 1. This curve gives the percentage of the first cost corresponding each year to 10% on the reduced balance. For example, the curve shows that the depreciation on a tool that has been in service five years will be 6. 6% of the original cost. If this cost was \$4500, the allowance for depreciation during the sixth year according to the 10% reducing balance method is \$4500 × .066 = \$297. Since this is 10% of the reduced cost, the value of the tool at the end of the fifth year is \$2970.

3 Tools designed for special work will be discontinued after a comparatively limited period, and therefore, depreciate in value much more rapidly than is indicated by the foregoing method: a special allowance frequently made for such tools is generally known as *utility depreciation.*

4 Table 1 contains a summary of machine hour rates obtained by this method. It is assumed that machines have been installed six years, so that the depreciation is 6% on a basis of 10% reducing balance.

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the meeting of the American Society of Civil Engineers, March 2, in the Society Building, 220 W. 57th Street, New York, a paper entitled, The Improved Water and Sewage Works of Columbus, O., was presented by John H. Gregory.

On March 16th two papers were presented, A Concrete Water Tower by A. Kempkey, Jun.Am.Soc.C.E., and Some Mooted Questions in Reinforced Concrete Design, by Edward Godfrey, Mem.Am.Soc.C.E.

AMERICAN INSTITUTE OF MINING ENGINEERS

The annual convention of the American Institute of Mining Engineers, in which the members of The American Society of Mechanical Engineers were invited to participate, opened on March 1 in the Carnegie Lecture Hall, Pittsburg. In the absence of Julian Kennedy, Dr. John A. Brashear, Mem.Am.Soc.M.E., gave an address of welcome. A great many interesting papers were presented during the three days which followed, including, The Development of Hindered Settling Apparatus, by Prof. R. H. Richards of the Massachusetts Institute of Technology; The Systematic Exploitation of the Pittsburg Coal Seam, by F. Z. Schellenberg of Pittsburg; A Commercial Fuel Briquette Plant, by W. H. Blauvelt of Syracuse, N. Y., Mem.Am.Soc.M.E.; The Gaseous Decomposition Products of Black Powder, by C. M. Young, Lawrence, Kan.; A New Method of Cyaniding Gold and Silver Ores, by E. Gibbon Spilsbury of New York, Mem.Am.Soc.M.E.; The Huronian as a Gold Bearing Terrane, by Dr. Robert Bell, of the Canadian Geological Survey; The Introduction of the Basic Steel Process in the United States, by Geo. W. Maynard of New York; Electric Mine Hoists, by David B. Rushmore of Schenectady, N. Y., Mem.Am.Soc.M.E.; and The Investigations of Structural Materials for Use in Federal Buildings, by E. F. Burchard of the Geological Survey. J. A. Holmes, of the U. S. Geological Survey, Mem. Am. Soc. M. E., also gave a brief paper on the work of the technological branch

at Pittsburg, which was largely explanatory of the plant and work of the survey testing station at Pittsburg. This station was later visited by the members and a series of highly interesting tests were conducted in their presence. Other excursions were also planned and carried out successfully. On the evening of March 2, Dr. D. T. Day of Washington gave a lecture on The Accumulation of Petroleum in the Earth.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The regular monthly meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineering Societies Building, New York, on Friday, March 11, 1910. This meeting was under the auspices of the Industrial Power Committee. Papers were presented as follows: Electric Mine Hoists, by D. B. Rushmore, Mem. Am.Soc.M.E., and K. A. Pauly; and Large Electric Hoisting Plants, by Wilfred Sykes.

Institute Meetings will be held, March 30-April 1, in Charlotte, N. C., and April 21, in San Francisco, Cal. A notice of papers to be read will be found in another department. The next New York Meeting will be held April 8.

CONSERVATION DISCUSSED AT THE NEW HAVEN ECONOMIC CLUB

At a dinner given by the Economic Club of New Haven, Thursday evening, February 24, 1910, The Conservation of our National Resources was presented from different viewpoints by speakers of wide reputation. Calvin W. Rice, Secretary Am.Soc.M.E., spoke on the great work now being conducted by the Government in relation to forests, lands and minerals. He was followed by Charles N. Chadwick, one of the commissioners of the board of Water supply of New York, now constructing an aqueduct from the Catskill mountains to New York City. Mr. Chadwick addressed the gathering on the importance of the conservation of water, upon which the great majority of the other resources are dependent. George W. Woodruff, of New York, former Assistant Attorney-General, emphasized the great economic importance of the preservation of resources. The last speech, by Prof. Herman H. Chapman, acting dean of the Yale Forestry School, dwelt on conservation as related to forests and said that it had been the mission of the United States forest service to actually demonstrate the true meaning of the word conservation as applied to the forests on our public lands in the West.

Among the members and guests present were Henry B. Sargent, Mem.Am.Soc.M.E., Prof. L. P. Breckenridge, Mem.Am.Soc.M.E., Dr. W. L. Phillips, Max Adler, Samuel R. Avis, Dr. Henry Spang.

INSTITUTION OF MECHANICAL ENGINEERS

The Institution of Mechanical Engineers held its annual meeting February 18, 1910, in the institution house, Storey's Gate, St. James's Park, London, S. W., and elected the following officers for the ensuing year: J. A. F. Aspinwall, President, A. T. Tannett Walker and Edward B. Ellington, Vice-Presidents.

The President called upon Dr. Glazebrook of the National Physical Laboratory to resume the discussion on the ninth report to the Alloys Research Committee on The Properties of Some Alloys of Copper, Aluminum and Manganese, presented at the previous meeting by Dr. Rosenhaim and F. C. A. H. Lantsberry. Dr. Glazebrook was followed by Sherard Cowper-Coles, H. F. Donaldson, H. L. Heathcote and Loughnan Pendred, with a closure by Dr. Rosenhaim.

INTERNATIONAL CONGRESS OF INVENTORS

The first annual convention of the International Congress of Inventors will be held in Rochester, N. Y., June 13-18, 1910. This association was established in 1906 and incorporated in 1907, with the aim of uniting the inventors of the world for the purpose of obtaining patent law reforms and protecting the interests of its members. An exhibition of patents and models will be held in connection with the convention, and will include both recent inventions and some of those of particular interest patented during the early years of the U. S. Patent Office.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION

At the eleventh annual convention of the American Railway Engineering and Maintenance of Way Association in Congress Hall, Chicago, Ill., March 15-17, 1910, reports were presented on uniform rules, signals and interlocking; conservation of natural resources; economics of railway location; wood preservation; standard specifications for cement, masonry and buildings, and other subjects of interest.

AIR BRAKE ASSOCIATION

At the seventeenth annual convention of the Air Brake Association to be held in Indianapolis, Ind., beginning May 10, 1910, committee reports will be received on the following topics: Air Brake Instruction, Examination and Rating; Air Pump Piping, Fittings and Connections; Best Arrangement of Air Pump and Main Reservoir Capacity for 100-Car Train Service; Brake Cylinders and Connections and Recommendations for Overcoming Troubles due to Cylinder Leakage; Questions and Answers on New York Brake Equipment; Questions and Answers on Westinghouse Equipment; Recommended Air Brake Practice; Inspection and Cleaning of Triple Valves and Brake Cylinders; the Past Year's Developments in Air Brakes.

AMERICAN ELECTROCHEMICAL SOCIETY

The Spring Meeting of the American Electrochemical Society will be held in Pittsburg, Pa., on May 4-7, 1910. On Wednesday, May 4, at 2.00 p.m., it is proposed to make a visit of inspection to the technological testing plant of the U. S. Geological Survey. Other excursions will be to the Park Company's Crucible Steel Mills, Carnegie Steel Company's Dried Blast Plant at Isabella Furnace, Jones and Laughlin's Steel Works (Talbot Continuous Steel Process), Pennsylvania Lead Smelting Company, Nernst Lamp Factory, Oxy-Actylene Welding Company; with an all-day excursion, visiting the Allegheny Plate Glass Works at Glassmere, Westinghouse Electric Works at East Pittsburg, the Firth-Stirling Works at Demmler (Heroult electric steel furnace in operation), Carnegie Steel Works at Homestead (combined open-hearth electric furnace in operation).

This is the first gathering of the society at Pittsburg. A fine program and a highly interesting meeting is assured.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

At the regular monthly meeting of the Engineers' Society of Western Pennsylvania, held March 15, 1910, President E. K. Morse, in response to a request made by the Pittsburg Chamber of Commerce, appointed the following Committee to report on the question of raising the bridges over the Allegheny River at Pittsburgh: Geo. S. Davison, Mem.Am.Soc.C.E.; Julian Kennedy, Mem.Am.Inst.M.E.; F. L. O. Wadsworth, Mem.Am.Soc.M.E.; John N. Chester, Mem.Am.Soc.-

M.E.; Emil Gerber, Mem.Am.Soc.C.E. The importance of the questions involved, both engineering and financial, may be realized from the fact that there are eight bridges affected, over a river averaging 1000 feet in width. A paper on Floods in the River Seine was read by Thos. P. Roberts of the U. S. Engineer's Office, Pittsburg.

IDAHO SOCIETY OF ENGINEERS

On February 12 the Idaho Society of Engineers was organized at Boise, Idaho, with 70 charter members representing surveyors and the four leading branches of engineering. It is the outgrowth of the Idaho Civil Engineers and Surveyors Association, and has been organized mainly through the work of Gen. Darwin A. Utter, United States surveyor-general for the State, who was elected president. In addition to the work of organization, papers were read on Dam Building, Railroad Construction, Water Power, Milling Ores, Irrigation and Municipal Engineering. Meetings will be held at Boise on the second Tuesday of each month.

UNIVERSITY OF KANSAS

The new engineering buildings of the University of Kansas were formally dedicated on February 25, 1910, in the presence of some 500 visitors, including alumni, engineers from other schools, and other interested persons. The program included three addresses in the chapel in the afternoon, by Prof. F. O. Marvin, Dean of the School of Engineering, Prof. Richard C. Maclaurin, President of Massachusetts Institute of Technology, and Ernest R. Buckley, President of the American Mining Congress. The dedication ceremony itself was held a little later, in the new mechanical and electrical engineering building, and was followed by a banquet at the Robinson gymnasium in the evening.

DETROIT INDUSTRIAL EXPOSITION

The city of Detroit, Mich., is planning a great industrial exposition to be held under the auspices of the Board of Commerce, June 20-July 6, 1910. The exposition ground will be located on the Detroit River where a huge building will be erected and used in conjunction with the Wayne Pavilion. The display promises to be one of the most unique ever arranged outside of a world's fair. It is claimed that 100,000

different articles are manufactured in the 3000 shops of the city, the products ranging from pins to steamships, a variety rivaled by the outputs of few other American cities. The processes as well as the results will be shown, with the purpose of teaching the world the variety, extent and quality of the city's products. The committee in charge is composed of 275 of the leading manufacturers of Detroit.

PERSONALS

Henry A. Allen has been appointed consulting engineer for the Department of Public Works, Chicago, Ill.

F. E. Bocorselski, who has been connected with the Baush Machine Company as superintendent and designer, has resigned his position to become assistant mechanical superintendent of the American Locomotive Company, with headquarters at Richmond, Va.

Claude A. Bulkeley, chief engineer of the board of education, St. Louis, Mo., has become associated with the firm of Marks & Woodwell, New York.

I. Francis Burton, formerly assistant superintendent of the Victor Talking Machine Company, Philadelphia, Pa., has been appointed superintendent of the company.

Charles F. Dixon has become connected with the engineering department of the New England Engineering Company, New Haven, Conn.

John M. Ewen has resigned his position as harbor commissioner of Chicago, Ill.

E. S. Farwell, consulting engineer, of New York, has become connected with the Yellow Pine Paper Mill Company, Orange, Tex., as general manager.

M. P. Fillingham, consulting engineer, New York, has assumed charge of the Eastern interests of the Fawcus Machine Company, of Philadelphia, Pa.

Francis L. Gilman, formerly associated with the American Telephone and Telegraph Company, New York, has become general manager of the Missouri and Kansas Telephone Company, Kansas City, Mo.

George P. Gilmore, recently local engineer of the American Thread Company, Fall River, Mass., has opened a power and equipment engineering office in the same city.

B. S. Hughes has severed his direct connection with the Champion Coated Paper Company, Hamilton, O., and the Champion Fibre Company, Canton, N. C., to engage in general engineering practice, with offices in Cincinnati, O.

F. W. Jackson, formerly district manager for the Harrisburg Foundry and Machine Works, Baltimore, Md., has been transferred to the managership of the company's business at Chicago.

Walter C. Kerr has been elected third vice-president of the Merchants' Association of New York.

Alfred H. Knight has become connected with the Packard Motor Car Com-

pany, Detroit, Mich. as carriage chassis engineer. He was until recently assistant professor of mechanical engineering at the University of Michigan, Ann Arbor, Mich.

F. E. Matthews, consulting refrigerating engineer, New York, has become assistant manager of the cold storage insulation department of H. W. Johns-Manville Co., New York.

Geo. R. Murray has been appointed president of the Murray Stone Co., successors to the Maxwell-Rolf Stone Company.

John C. Parker, electrical engineer for the Rochester Railway and Light Company, has been appointed non-resident lecturer in electric energy transmission at the University of Michigan, Ann Arbor, Mich.

W. P. Pressinger, formerly identified with the W. P. Pressinger Company, New York, has been appointed vice-president and manager of sales of the Keller Manufacturing Company, Philadelphia, Pa.

Paul S. Rattle, mechanical engineer of B. M. Osbun Co., Chicago, Ill., has become associated with the sales organization of the Hicks Locomotive and Car Works, Chicago.

Robert W. Rogers, formerly identified with the Erie Railroad, Meadville, Pa., has entered the service of the C. A. Stickney Co., St. Paul, Minn., as mechanical engineer.

Clement F. Smith, recently associated with the Westinghouse Air Brake Company, Wilmerding, Pa., has opened an office in Cleveland, O.

Ephraim Smith, who has been the New England sales manager of the Colonial Steel Company since its organization in 1901, has resigned his position on account of ill health.

Roy B. Smith has become inspector of the Pennsylvania Lines, West, Columbus, O. Until recently he was foreman of motive power and equipment of the C. L. & N. Railway, Cincinnati, O.

B. V. Swenson has become connected with Barron G. Collier. Inc., New York. He was formerly secretary and treasurer of the American Street and International Railway Association, New York.

Cary D. Terrell, formerly assistant manager of sales of the Pressed Steel Car Company, St. Louis, Mo., has become sales agent of the American Car and Foundry Company, St. Louis, Mo.

Henry R. Towne has been elected president of the Merchants' Association of New York.

Theron H. Tracy, president of the Tracy-Devereaux Co., Los Angeles, Cal. has been appointed president of the Durostone Company of America, San Diego Cal.

A. W. Waern has become associated with Jos. H. Wallace & Co., New York.

He was formerly engineer of the machinery department of the Bethlehem Steel Company, South Bethlehem. Pa.

Prof. Ira H. Woolson, adjunct professor of civil engineering, Columbia University, in charge of fire tests of building materials, has resigned to become consulting engineer for the National Board of Fire Underwriters.

Roydon V. Wright, for several years managing editor of the American Engineer and Railroad Journal, has become a member of the editorial staff of the Railway Age Gazette, with direct supervision over the mechanical department

CURRENT BOOKS

THE ECONOMY FACTOR IN STEAM-POWER PLANTS. By George W. Hawkins. *Hill Pub. Co., New York, 1908.* Cloth, 8vo., ix+ 133 pp., illustrated. Price, $3 net.

Contents: Introduction; Part I, Individual Apparatus: Boilers, Engines, Electrical Generators, Condensing Apparatus, Feed-Pumps, Oil-Pumps, Oil Burners, Radiation, Leakage, Feed-Water Heaters, Fuel Economizers; Part II, The Factor of Evaporation; Part III, Complete Plant Economy (Full Rated Load): Introductory, Non-Condensing Plants, Surface-Condensing Plants, Jet-Condensing Plants, Pumping Plants, Examples; Part IV, Complete Plant Economy (Variable Load): Phases of the Problem, Method of Solution; Conclusion.

THE GAS TURBINE. Progress in the Design and Construction of Turbines Operated by Gases of Combustion. By Henry Harrison Suplee, B.Sc. *J. B. Lippincott Co., Philadelphia, 1910.* Cloth, 8vo., 262 pp., with diagrams. Price, $3.

Contents: Introduction; Historical; Discussion before the Institution of Mechanical Engineers; Discussion before the Society of Civil Engineers of France; Actual Behavior of Gases in Nozzles; Practical Work of Armengaud and Lemale; General Conclusion.

HEAT ENERGY AND FUELS. Pyrometry, Combustion, Analysis of Fuels and Manufacture of Charcoal, Coke and Fuel Gases. By Hanns v. Jüptner. Translated by Oskar Nagel, Ph.D. *New York, McGraw Pub. Co.,1908.* Cloth, 8vo., 306 pp., illustrated. Price, $3.

Contents: Introduction: General Remarks, Forms of Energy. Vol. I. Heat Energy and Fuels. Part I. Heat Measurement, Combustion and Fuels: The Measurement of High Temperatures (Pyrometry); Pyrometry, Optical Methods of Measuring Temperatures; Combustion Heat and its Determination; Direct Methods for Determining the Combustion Heat; Incomplete Combustion; Combustion Temperature; Fuels (in general); Wood; Fossil Solid Fuels (in general); Peat; Brown Coal (Lignite); Bituminous and Anthracite Coals; Artificial Solid Fuels; Charcoal; Peat-Coal, Coke and Briquettes; Coking Apparatus; Liquid Fuels; Gaseous Fuels; Producer Gas; Water Gas; Dowson Gas, Blast Furnace Gas and Regenerated Combustion Gases; Apparatus for the Production of Fuel Gases.

THE RESISTANCE AND PROPULSION OF SHIPS. By William F. Durand. Second edition, thoroughly revised. *New York, John Wiley & Sons, 1909.* Cloth, 8vo., vii + 427 pp. Price, $5.

Contents: Resistance; Propulsion; Reaction between Ship and Propeller; Propeller Design; Powering Ships; Trial Trips.

THE MODERN GAS ENGINE AND THE GAS PRODUCER. By A. M. Levin. First edition. *New York, John Wiley & Sons, 1910.* Cloth, 8vo., 16 + 485 pp., illustrated. Price, $4.

Contents: Introduction to Thermodynamics; Design Constants and Formulas; Theoretical Analyses of the Gas-Engine Cycles; Power, Size and Speed of Gas-Engines; Fuels, Combustion; Gas-Engine Fuels—The Proportioning of Mixtures and Relation of these to the Size of the Engine; Alcohol Fuels; Features of the Practical Gas-Engine Cycle; The Fly-Wheel; The Crank Shaft; Engines Details; Governing; Engine Auxiliaries; Various Engine Types; Producer-Gas and Gas-Producers; Appendix.

FULFILMENT OF THREE REMARKABLE PROPHECIES IN THE HISTORY OF THE GREAT EMPIRE STATE, Relating to the Development of Steamboat Navigation and Railroad Transportation, 1808-1908. By Henry Whittemore. Cloth, 8vo., 80 pp.

Contents: Early Experiments in Steamboat Navigation; James Rumsey's Claim to the Discovery of Steamboat Navigation; Claims of Nathan Read, Nicholas Roosevelt, Capt. Samuel Morey and Elijah

Ormsbee; Inventions of Col. John Stevens and Robert L. Stevens in Steam Navigation; Robert Fulton–His Successful Efforts in the Development of Steam Navigation with the Assistance of Robert L. Livingston; Improvements in Steamboats and Increased Facilities for Steam Navigation on the Hudson River; Rivalry between Steamboat Companies—Steamboat Disasters—Great Improvement in Steamboat Construction; Railroad Transportation.

AUTOMOBILES. By Hugo Diemer, M.E. *Chicago, American School of Correspondence, 1909.* Cloth, 192 pp., illustrated. Price, $1.50.

Contents: Component Parts of a Motor-Car; Power Plant of a Gasolene Car; Controlling Mechanism and Transmission; Care and Operation of Motor-Cars; Selection and Classification of Motor-Cars; Index.

TABLES AND DIAGRAMS OF THE THERMAL PROPERTIES OF SATURATEDAND SUPERHEATED STEAM. By Lionel S. Marks and Harvey N. Davis. *New York, Longmans, Green & Co., 1909.* Cloth, 8vo., 106 pp.,illustrated. Price, $1, net.

Contents: Part I: Tables and Diagrams; Part II: The Use of the Diagrams; Part III: Discussion of Sources.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. List of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Mining Congress. Monthly bulletin. Vol. 13, no. 2. *Denver, 1910.*

American Water Works Association. Proceedings, 1909. *Baltimore, 1909.* (Gift of American Water Works Association.)

Approximate Cost of Mill Buildings. By C. R. Main. *Waltham, 1910.*

Automobiles. By Hugo Diemer. *Chicago, 1909.* (Gift of author.)

Beiträge zür Geschichte der Technik und Industrie. Vol. 1, 1909. *Berlin, Springer, 1909.* (Gift of Verein deutscher Ingenieure.)

Broadening the Field of the Marine Steam Turbine: the Problem and its Solution. The Melville and Macalpine Reduction Gear. *Pittsburg, 1909.*

Carnegie Institution of Washington, Department of Terrestrial Magnetism. Annual report of the director, 1909. (Gift of the Department.)

Civil Engineer's Pocket-book. Ed. 19. By J. C. Trautwine. *New York, J. Wiley & Sons, 1909.* (Gift of J. C. Trautwine, Jr., and J. C. Trautwine, 3d.)

Control of Flies and Other Household Insects. Bulletin 136, N. Y. State Museum. By E. P. Felt. *Albany, 1910.*

Design and Construction of Internal-Combustion Engines. By Hugo Guldner. *New York, 1910.*

Deutsch-Amerikanischen Techniker-Verbandes. Verbands-Statuten, 1910. *New York, 1910.*

Dictionnaire de la Langue Française. Vol. 1–4 and supplement. *Paris, 1884–1885.*

Economy Factor in Steam-Power Plants. By G. W. Hawkins. *New York, Hill Publishing Co., 1908.*

Elements of Machine Design. Part 1, General principles, strength of materials, etc. *London, 1909.*

Elevator Service. By R. P. Bolton. *New York, 1908.*

Energy: Work, Heat and Transformations. By S. A. Reeve. *New York, McGraw-Hill Book Company, 1909.*

ENGINEERS' AND FIREMEN'S LICENSE LAW. BOILER INSPECTION LAW. Rules Formulated by the Board of Boiler Rules, Commonwealth of Massachusetts. *Boston, 1909.* (Gift of John A. Stevens.)

GAS ENGINE. By C. P. Poole. *New York, Hill Publishing Co., 1909.* (Gift of author.)

DIE GASMASCHINE. Ed. 5. By R. Schöttler. *Berlin, 1909.*

GAS TURBINE. By H. H. Suplee. *Philadelphia, 1910.* (Gift of author.)

GROSSGASMASCHINENBAU IN AMERIKA. By Dr. Rieppel, Jr. (Reprint Zeitschrift Vereines deutscher Ingenieure, 1909.) (Gift of author.)

HANDBOOK OF SMALL TOOLS. By Erik Oberg. *New York, 1908.*

HEAT ENERGY AND FUELS. By Hanns v. Juptner. *New York, McGraw Publishing Co., 1908.*

HENLEY'S ENCYCLOPÆDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES. Vol. 5 (Spe-Z). *New York, N. W. Henley Publishing Co., 1909.*

HYDRAULIC ELEVATORS. By Wm. Baxter, Jr. *Chicago, 1905.*

ILLUSTRATED TECHNICAL DICTIONARY. Vol. 5, Railway construction and operation; Vol. 6, Railway rolling stock. *New York, 1909.*

LARGE GAS ENGINES. By P. R. Allen. (Reprinted from Cassier's Magazine, July–September 1909.) (Gift of Cassier's Magazine.)

LINSEED OIL AND OTHER SEED OILS. By W. D. Ennis. *New York, D. Van Nostrand Co., 1909.*

LOSSES OFF TRANSMISSION LINES, DUE TO BRUSH DISCHARGE, WITH SPECIAL REFERENCE TO THE CASE OF DIRECT CURRENT. (Institution of Electrical Engineers, 1909.) (Gift of Calvin W. Rice.)

MILLWRIGHTING. By J. F. Hobart. *New York, 1909.*

MODERN ELECTRIC TIME SERVICE. By F. H. Jones. (Institution of Electrical Engineers, 1909.) (Gift of Calvin W. Rice.)

MODERN GAS-ENGINE AND THE GAS-PRODUCER. By A. M. Levin. *New York, J. Wiley & Sons, 1910.*

MOTOR TRACTION. Vol. 9, no. 421–date. *London, 1909–date.*

NEW YORK CITY, DEPARTMENT OF BRIDGES. Report on Manhattan Bridge. By Ralph Modjeski. 1909. *New York, 1909.* (Gift of the Department.)

POSTULADOS DE LAS CLASES OBRERAS Y DE LOS DESCALIDOS Y PROLETARIOS, A PRESENCIA DE LA CIENCIA SOCIAL Y, EN ESPECIAL, DE LA ECONOMIA POLITICA. Vol. 2. *Santiago de Chile, 1909.* (Gift of Secretary-General, Fourth Scientific Congress [First Pan-American].

PRACTICAL COLD STORAGE. By Madison Cooper. *Chicago, 1905.*

PRINCETON UNIVERSITY. Directory of Living Graduates and Former Students, 1908. *Princeton, 1908.*

PRODUCER-GAS-FIRED FURNACES. By Oscar Nagel. *New York, 1909.*

RESISTANCE AND PROPULSION OF SHIPS. Ed. 2. By W. F. Durand. *New York J. Wiley & Sons, 1909.*

SMITHSONIAN INSTITUTION. Annual report. 1908. *Washington, 1909.*

SOCIÉTÉ DES INGENIEURS CIVILS DE FRANCE. Inauguration du Nouvel Hotel, January 1897. *Paris, 1897.*

STEAM POWER PLANT PIPING SYSTEMS. By W. L. Norris. *New York, 1909.*

TABLES AND DIAGRAMS OF THE THERMAL PROPERTIES OF SATURATED AND SUPERHEATED STEAM. By L. S. Marks and H. N. Davis. *New York-London, Longmans, Green & Co., 1909.* (Gift of author.)

THEORY AND PRACTICE OF MODERN FRAMED STRUCTURES. Part 1, Stresses in simple structures. Ed. 9. By J. B. Johnson, C. W. Bryan and F. E., Turneaure. *New York, 1910.*

TYPES AND DETAILS OF BRIDGE CONSTRUCTION. Parts 1–3. By F. W. Skinner. *New York, 1904, 1906, 1908.*

U. S. LIBRARY OF CONGRESS. Duplicate periodicals and serials available for exchange January 1910. *Washington, 1910.*
———Want list miscellaneous publications 1909. *Washington, 1909.*

U. S. LIBRARY OF CONGRESS. Report of Librarian, 1909. *Washington, 1909.*
———Publications issued since 1897. *Washington, 1910.*

UNIVERSITY OF PENNSYLVANIA. Catalogue, 1909–1910. *Philadelphia, 1910.*
VEREIN DEUTSCHER INGENIEURE. ZUR FEIER DES 50 JÄHRIGEN BESTEHENS DES VEREINES. 1856–1906.

———BERLINER BEZIRTSVEREIN DEUTSCHER INGENIEURE. 1856–1906. *Berlin, 1900.*

WATUPPA WATER BOARD. 36th Annual Report. *1910.*

EXCHANGES

JUNIOR INSTITUTION OF ENGINEERS. Journal and Record of Transactions. Vol. 19. *London, 1909.*

LIVERPOOL ENGINEERING SOCIETY. Transactions. *Liverpool, 1909.*

RAILWAY SIGNAL ASSOCIATION. List of Members, 1910. *Bethlehem, 1910.*

SÄCHSISCHER DAMPFKESSEL REVISIONS VEREIN, CHEMNITZ. Ingenieur-Bericht, 1909. *Chemnitz.*

TRADE CATALOGUES

AMERICAN SPIRAL PIPE WORKS, *Chicago, Ill.* Spiral riveted pipe, forged steel pipe flanges, hydraulic and exhaust steam supplies, 20 pp.

ASBESTOS PROTECTED METAL CO., *Canton, Mass.* Asbestos protected metal for roofing, siding, ceiling, and interior finish, 8 pp.

Economy Drawing Table Co., *Toledo, O.* Drawing tables, sectional filing cases and specials in this line, for engineers, architects, contractors, manual training schools, etc., 48 pp.

General Electric Co., *Schenectady, N. Y.* Building lighting with general electric tungsten and tantalum lamps, 16 pp. Price list No. 5211, G. E. tantalum incandescent lamps, 5 pp.; November 1909, Index to bulletins published, 9 pp.; Bulletin No. 4703A, Variable release air brake equipment, 11 pp.; Bulletin No. 4714, Railway signal voltammeter, type S, 3 pp.; Bulletin No. 4715, G. E. 210 Railway motor, 16 pp.

Hagan Gas Engine & Mfg. Co., *Winchester, Ky.* Catalogue C, 2 to 100 h.p. Hagan gas and gasolene engines, 39 pp.

Jeffrey Mfg. Co., *Columbus, O.* Booklet No 33, Jeffrey wire cable conveyors, 24 pp.; Booklet No. 34, Jeffrey standard elevator buckets, 24 pp.

Lamson Consolidated Store Service Co., *Boston, Mass.* Two-wire cord-propulsion parcel carriers for stores, 8 pp.

Manufacturing Equipment and Engineering Co., *Boston, Mass.* All-metal, sanitary, and fireproof equipment for factories, foundries, offices, hospitals, etc., 32 pp.

National Vacuum Heating Co., *Marshalltown, Iowa.* Dunham vacuo-vapor system of heating, 40 pp.

Northwestern Expanded Metal Co., *Chicago, Ill.* Reinforcing for sewers, tanks, and walls, 16 pp.

Ohio Brass Co., *Mansfield, O.* Bulletin of electric railway and mine haulage material, 24 pp.

Remington Typewriter Co., *New York, N. Y.* Remington Notes, vol. 2, No. 2, containing notes of interest to users of the Remington typewriter, 16 pp.

Francis H. Richards, *New York, N. Y.* Useful information concerning patents and inventions, 38 pp.

Russel Wheel and Foundry Co., *Detroit, Mich.* Views of Russel skidding and loading machines in operation, 40 pp.; catalogue of different styles and patterns of Russel cars for handling logs, lumber, etc., 46 pp.

Joseph T. Ryerson & Sons, *Chicago, Ill.* March, 1910. Ryerson Monthly Journal and Stock List of iron and steel supplies, 144 pp.

Chas A. Stickney Co., *St. Paul. Minn.*, Bulletin No. 1137, The Stickney oil engine and 57 points in which it excels other engines, 16 pp.

Underfeed Stoker Co. of America. *Chicago, Ill.* Publicity Magazine, February 1910, devoted to the interests of the Jones mechanical stoker, 15 pp.

Wagner Electric Mfg. Co., *St Louis, Mo.* Bulletin 89—Type BW polyphase induction motor, 8 pp.

Warner & Swasey Co., *Cleveland, O.* Warner & Swasey prism terrestrial telescope, 3 pp.

UNITED ENGINEERING SOCIETY

GIFT OF E. E. OLCOTT

ALBANY INSTITUTE. Transactions. Vol. 5. *Albany, 1867.*

NEW YORK STATE. Adjutant General. Annual report. Vol. 3. *Albany, 1868.*

NEW YORK STATE ENGINEER AND SURVEYOR. Annual report on canals. 1862, 1864. *Albany, 1863, 1865.*

——Annual report on railroads. 1862, 1865. *Albany, 1863, 1866.*

NEW YORK STATE RAILROAD COMMISSIONERS. Report, Vol. 1, 1885. *Albany, 1886.*

SWEET, S. H. Documentary sketch of New York State canals. *Albany, 1863.*

REGISTER TILL PATENT MEDDILADE AF KUNGL. PATENTBYRAN. 1885–1908 and supplement to 1905. *Stockholm, 1890–1909.*

TRADE CATALOGUES

GIROD FURNACES, *Ugine, Savoie.* Steels made by the Girod process, 16 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

015 Sales manager for improved type of heavy-duty gas and gasoline engines, up to 25 h.p., for industrial and farm purposes. Applicant should state experience in similar capacity and what results he could agree to produce.

016 Large blast-furnace plant in the South wants at once draftsman between twenty-five and thirty years old, technically educated, with sufficient breadth to do testing and various work about the plant. Climate agreeable and healthful. Exceptional opportunity for the right man.

017 Wanted, by a large iron and steel company, superintendent of shops; include pattern, foundry, blacksmith, pipe and machine shops; combined force of about 500 men. Prefer technically educated man. Must be an organizer, familiar with modern methods and able to hold production costs on reasonable basis. None but high class man need apply. Salary $3600 per annum.

018 Wanted: thorough practical and theoretical man, to take charge of the production and the development of a concern located in the Middle West, manufacturers of injectors, valves, etc. Must be familiar with railroad operating conditions and thoroughly up-to-date in brass foundry and machine shop practices.

019 Instructor in mechanical drawing and machine design in a technical school near New York. Previous teaching experience desirable but not essential. Salary about $1500 with good opportunity for advancement.

020 Assistant engineering editor on prominent trade journal; excellent opportunity for rapid advancement. State experience fully; communications confidential.

021 Opportunity for engineer with business experience to acquire interest in business of manufacture of all classes of hydraulic machinery, steam hammers, etc. Location Pennsylvania.

MEN AVAILABLE

41 Lawyer-engineer, desires position as salesman. Age 44; member United States Supreme Court; legal and technical education, twenty-five years successful experience combined with sales, steam, electrical and gas driven power plants, water and gas works, chemicals, every description of machinery and its product; specialty, automobile salesman. Extensive acquaintance throughout the United States.

42 University graduate in mechanical engineering, a student member, located on the Pacific Coast, desires position with eastern gas engine company; at present designing medium and large liquid fuel engines, stationary and marine; testing and machine shop experience.

43 Junior member, graduate mechanical and electrical engineer, Mass. Inst. of Technology; experience in erection and operation of electric power plants; has served time in large railroad shops and understands shop methods thoroughly. Location immaterial.

44 Mechanical engineer, specialized in manufacturing, thoroughly competent to take responsible position. As superintendent and manager has successful practical experience in foundry and machine shop; gray iron and brass mixtures by analysis, machine molding, interchangeable machine work, systematizing, cost-keeping, piece work, etc.; knows how to equip plant and organize men to secure large output and low costs.

45 Cornell graduate, married, nine years' experience with engineers, contractors and industrial companies, in drafting room, office and on construction; desires to make a change.

46 Mechanical engineer, Member, technical graduate; broad practical knowledge of engineering, good systematizer, especially able as a producer, severa- years' experience in engineering work, in charge of large engineering departl ments; desires position with first-class firm as chief engineer, or similar position.

47 Man with seventeen years' experience in office and shop of manufacturing concern, general experience in this line and executive work; would like to meet some responsible concern in New York or vicinity who want salesman or competent office manager.

48 Engineer, thirty years old, technical graduate, desires position preferably in Chicago, as factory manager of a small but growing plant. Four years' shop and drafting experience, four years installing cost and shop systems, experienced in laying out and constructing power plants and industrial works.

49 Member, with over twenty years' practical experience in designing, superintending and managing work in shop and field, desires position, preferably near Philadelphia.

50 Engineer, wants the New York agency for the best automobile delivery wagon and automobile truck in the United States.

51 Member, now general mechanical superintendent, desires change. Ten years' experience as mechanical engineer and superintendent, general transmission machinery, gas and Corliss engines. Thoroughly posted on rapid foundry, machine shop production and up-to-date appliances and methods.

52 Associate member, twenty-eight years of age, graduate marine and mechanical engineer, wishes to locate with some good, growing manufacturing concern in capacity of chief engineer, assistant chief engineer, chief draftsman or similar position, where the services of a mechanical engineer with an excellent theoretical, as well as practical training in the gas engine, producer, steam engine, power transmission and general engineering lines will be appreciated. Best references as to ability and character.

53 Associate, graduate mechanical engineer, fourteen years' experience in general engineering work, including machine shop work, testing, power plant design, construction and operation. Five years in electric railway work, involving civil, mechanical and electrical engineering; recently completed the remodeling of an electric railway and lighting power plant, now completing the construction of a large electric power plant. Good executive ability, experience in office methods, correspondence, etc. Wishes an executive position involving responsibility. Salary $2500.

54 Junior, technical graduate, at present mechanical engineer and assistant to manager of plant building high grade boilers. Experienced boiler designer. Desires similar position, or as assistant superintendent in large plant.

55 Junior member, age thirty-one, desires to make a change. Several years designing, testing and installing steam turbines, steam engines, condensers, etc.; varied experience in engineering lines, and electrical work. Desires position with large industrial corporation, or in office of consulting or contracting engineer.

56 Graduate mechanical engineer, Harvard University, S.B. and M.M.E., twenty-five years of age, experienced in the organization and management of work shops, would like to obtain position with establishment manufacturing standard line of goods, or with consulting engineer engaged in workshop organization and management.

57 Member, desires position as mechanical engineer with concern developing new inventions; competent in designing, perfecting and simplifying mechanisms.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALDEN, Herbert W. (1908), Ch. Engr., Timken-Detroit Axle Co., Clark Ave., Detroit, Mich.

BORDEN, Wm. H. (Junior, 1905), Goldsboro, N. C., and *for mail*, 713 Seventh Ave., N., Seattle, Wash.

BULKELEY, Claude A. (1909), Cons. Mech. and Elec. Engr., 511 Terminal Bldg., 41st St. and Park Ave., New York, N. Y.

BURTON, Isaac Francis (1908), Supt., Victor Talking Mch. Co., and *for mail*, 5219 Walnut St., Philadelphia, Pa.

BUSH, Harold Montford (1894; 1905), Cons. Engr., 69 N. Fourth St., Columbus, O.

CAMPBELL, Jeremiah (Associate, 1896), 2 New St., East Boston, Mass.

CHESS, Harvey B., Jr. (Junior, 1909), Secy. and Wks Mgr., Consolidated Expanded Metal Cos., Rankin, and *for mail*, 814 Aiken Ave., Pittsburg, Pa.

COFFIN, Howard E. (1907), V. P., Hudson Motor Car Co., and 434 Cadillac Ave., Detroit, Mich.

DIXON, Charles F. (Junior, 1903), Engrg. Dept., New England Engrg. Co., 113 Church St., and *for mail*, 172 Ellsworth Ave., New Haven, Conn.

DOUGLASS, Wm. M. (1884), 306 Seventh Ave., Bethlehem, Pa.

FARWELL, E. S. (1899), Genl. Mgr., Yellow Pine Paper Mill Co., Orange, Tex.

FLEMING, Wills M. (1905; 1909), Ch. Draftsman, Deane Steam Pump Co., and *for mail*, 370 Maple St., Holyoke, Mass.

GILMAN, Francis L. (1908), Genl. Mgr., Missouri & Kansas Telephone Co., Kansas City, Mo.

GILMORE, George Parley (1909), Power and Equip. Engr., First Natl. Bank Bldg., and *for mail*, 109 Barre St., Fall River, Mass.

HILL, Robert J. (Associate, 1904), 810 Marquette Bldg., Chicago, and 816 Sheridan Road, Wilmette, Ill.

HORTON, William H. (Junior, 1904), 7001 S. Park Ave., Chicago, Ill.

HUGHES, Burton Shelley (1908), Cons. Engr., 1014 Commercial Tribune Bldg., Cincinnati, O.

JACKSON, F. W. (1909), Dist. Mgr., Harrisburg Fdy. & Mch. Wks., 950 Marquette Bldg., Chicago, Ill.

KEITH, Thomas M. (Junior, 1905), Robins Conveying Belt Co., Park Row Bldg., New York, N. Y.

KNIGHT, Alfred H. (1909), Carriage Chassis Engr., Packard Motor Car Co., and *for mail*, 185 Seward Ave., Detroit, Mich.

LEE, Ralph A. (Junior, 1909), Asst. Bldg. Supt., with Walter Kidde, 140 Cedar St., New York, and *for mail*, 578 75th St., Brooklyn, N. Y.

LEE, Robert E. (Junior, 1907), 129 Chestnut St., Rutherford, N. J.

MATTHEWS, Fred Elwood (Junior, 1904), Asst. Mgr., Cold Storage Insulation Dept., H. W. Johns-Manville Co., 100 William St., New York, N. Y.

MEINHOLTZ, Herman Chas. (1909), V. P. and Supt., Heine Safety Boiler Co., 2449 E. Marcus Ave., and *for mail,* 4812 Greer Ave., St. Louis Mo.

MILLETT, Kenneth B. (Junior, 1908), Factory Supt., Protal Co., Bridgeport, Conn.

MINCK, Peter (Junior, 1909), Mech. Engr., with Edwin Burhorn, 71 Wall St., New York, N. Y., and *for mail,* 112 Gardner St., Union Hill, N. J.

MURRAY, Geo. R. (1903), Pres., Murray Stone Co., 914 Williamson Bldg., Cleveland, O.

MURRIE, John L. (Junior, 1905), Mech. Engr., Pub. Service Com., First Dist., Tribune Bldg., and *for mail,* 551 W. 178th St., New York, N. Y.

ORD, Henry C. (1905), Genl. Elec. Co., and *for mail,* 3 Eastern Ave., Lynn, Mass.

POULTNEY, John Livingston (1908), Contr. Engr., Land Title Bldg., Philadelphia, Pa.

POWELL, E. Burnley (Junior, 1904), Stone & Webster Engrg. Corp., 147 Milk St., Boston, Mass., and *for mail,* Houghton County Elec. Light Co., Houghton, Mich.

RATTLE, Paul S. (Junior, 1908), Sales Organization, Hicks Loco. & Car Wks., Chicago, and 459 Oak Park Ave., Oak Park, Ill.

REID, John Simpson (1898), Instr. Mech. Drawing and Design, Armour Inst. Tech., and 43 W. 33d St., Flat C, Chicago, Ill.

RICE, Alva C. (1890), Cons., Hyd. and Mech. Engr., 5 Oberlin St., Worcester, Mass.

ROUVEL, George W. (1907), Genl. Supt., Standard Portland Cement Co., Napa Junction, and Napa, Cal.

SERGEANT, Chas. H. (1895), 511 W. 134th St., New York, N. Y.

SMITH, Roy B. (Junior, 1905), Inspr., Pa. Lines West, and *for mail,* 106 S. Champion Ave., Columbus, O.

TALCOTT, Robt. Barnard (1907), Inspr. Mech. and Elec. Engrg., U. S. Post Office Bldg., Denver, Colo.

TAYLOR, Percy B. (1909), Cons. Engr., 196 Market St., Newark, N. J.

TERRELL, Cary D. (Junior, 1901), Sales Agt., Am. Car & Fdy. Co., 915 Olive St., St. Louis, Mo.

TRACY, Theron H. (1902), Pres., Durostone Co. of America, San Diego, Cal.

UNGER, John S. (1886), Cons. Engr., 1412 N. Y. Life Bldg., and *for mail,* 3344 Evanston Ave., Chicago, Ill.

WAERN, A. W. (1908), Cons. Engr., Jos H. Wallace & Co., Temple Court Bldg., New York, N. Y.

WALSH, Thomas J. (Junior, 1906), Stone & Webster Engrg. Corp., Boston, Mass., and *for mail,* Houghton County Elec. Light Co., Houghton, Mich.

WILDER, Clifton W. (1907), Asst. Elec. Engr., Pub. Service Com., 154 Nassau St., New York, N. Y.

WRIGHT, Roydon V. (1907), Supv. Mech. Dept., Railway Age Gazette, New York, N. Y., and *for mail,* 285 N. 20th St., East Orange, N. J.

NEW MEMBERS

BLANCHARD, Henry W. (1909), Mgr., Austral Iron Wks., E. W. Tarry Co., Ltd., and *for mail*, P. O. Box 1098, Johannesburg, Transvaal, South Africa.

RUCKER, B. Parks (1909), Elec. and Mech. Engr., Trust Bldg., Charlotte, N. C.

STODDARD, Elliott J. (1909), Parker & Burton, 603 Moffat Bldg., Detroit, Mich.

PROMOTIONS

HVID, Rasmus M. (1907; Associate, 1909), Am.Soc.M.E., 29 W. 39th St., New York, N. Y.

THURN, Theodore (1904; 1909), Engr., Genl. Elec. Co., 23 Water St., Yokohoma, Japan.

DEATHS

GOODALE, A. M., December 17, 1909.

GAS POWER SECTION

CHANGES OF ADDRESS

FLEMING, W. M. (1909), Mem.Am.Soc.M.E.
MATTHEWS, Fred E. (1908), Mem.Am.Soc.M.E.
MYERS, Theodore B. (Affiliate, 1909), 981 Bulls Ferry Rd., Woodcliff-on-Hudson, N. J.
SERGEANT, Chas. H. (1908), Mem.Am.Soc.M.E.
UNGER, John S. (1909), Mem.Am.Soc.M.E.
WILDER, Clifton W. (1908), Mem.Am.Soc.M.E.

NEW MEMBERS

BIGELOW, Lucius S. (Affiliate, 1910), Pres., Light Pub. Co., 106 Fulton St., and Pres., Periodicals Pub. Co., New York, N. Y.
HARRIS, William J., Jr. (Affiliate, 1910), Junior Engr., Tech. Branch, U. S. Geolog. Survey, Washington, D. C.
HOBART, Frank G. (1910), Mem.Am.Soc.M.E.
IRWIN, Arthur Charles (Affiliate, 1910), Erecting Engr., Tait Producer Co., New York, and *for mail*, 33 E. Smith Ave., Corona, L.I., N. Y.
KENNEY, Lewis H. (1910), Mem.Am.Soc.M.E.
MYERS, David M. (1910), Mem.Am.Soc.M.E.
RANDALL, Dwight T. (1910), Mem.Am.Soc.M.E.
SMITH, Earl B. (Affiliate, 1910), Asst. Prof. Expl. Mech. Engrg., Drexel Inst., Philadelphia, Pa.

STUDENT BRANCHES

CHANGES OF ADDRESS

CHU, P. F. (Student, 1909), 31 Inman St., Cambridge, Mass.
CUMPSTON, E. H., Jr. (Student, 1909), 2252 Washington Ave., Cincinnati, O.
GREEN, J. B. (Student, 1909), 4734 Kimbark Ave., Chicago, Ill.
HARKNESS, C. L. (Student, 1910), Association House, Champaign, Ill.
HOLLENBERGER, Theo. J. (Student, 1909), 63 N. Adolph Ave., Akron, O.
ILLMER, G. M. (Student, 1909), 2739 Calvert St., Baltimore, Md.
KUPPATRICK, H. J. (Student, 1909), Roseville, Ill.
LAWRENCE, J. H. (Student, 1909), 3120 Broadway, New York, N. Y.
NYLAND, Evert (Student, 1909), 1428 N. Bouvie St., Philadelphia, Pa.
PETERSON, A. G. (Student, 1909), Lodi, N. Y.
STEINBECK, C. E. (Student, 1909), 1029 N. Hunter St., Stockton, Cal.
STEWART, H. M. (Student, 1910), 2358 Ohio Ave., Cincinnati, O.

NEW MEMBERS

ARMOUR INSTITUTE OF TECHNOLOGY

CUMMINGS, G. F. (Student, 1910), 3360 Prairie Ave., Chicago, Ill.
HATMAN, J. G. (Student, 1910), 3653 Calumet Ave., Chicago, Ill.

BROOKLYN POLYTECHNIC INSTITUTE

BURKE, T. F. (Student, 1910), 125 W. 111th St., New York, N. Y.
HELWIG, Arthur (Student, 1910), 10th Ave. and 70th St., Brooklyn, N. Y.

CORNELL UNIVERSITY

DEXTER, R. L. (Student, 1910), 603 E. Seneca St., Ithaca, N. Y.
KONSTANKEWICZ, M. (Student, 1910), 208 Williams St., Ithaca, N. Y.
LEHMAN, M. G. (Student, 1910), Barnes Hall, Ithaca, N. Y.
MATTHAI, A. M. (Student, 1910), 810 University Ave., Ithaca, N. Y.
ROOS, D. G. (Student, 1910), 105 Highland Pl., Ithaca, N. Y.
WEED, R. W. (Student, 1910), 404 N. Cayuga St., Ithaca, N. Y.

PENNSYLVANIA STATE COLLEGE

HASSLER, Joseph A. (Student, 1910), Alpha Kappa Delta House, Pa. State College, State College, Pa.
HOFFMAN, William S. (Student, 1910), 492 Main Bldg., Pa. State College. State College, Pa.

MATTERN, J. Fred (Student, 1910), Alpha Kappa Delta House, Pa. State College, State College, Pa.
MINSKER, John W. (Student, 1910), 339 McAllister Hall, Pa. State College, State College, Pa.
MORGAN, Henry (Student, 1910), 339 McAllister Hall, Pa. State College, State College, Pa.
PURDY, Donald F. (Student, 1910), 314 E. College Ave., Pa. State College, State College, Pa.
RAHN, Robert M. (Student, 1910), 370 Main Bldg., Pa. State College, State College, Pa.
WHITE, J. Frank (Student, 1910), 132 Beaver Ave., Pa. State College, State College, Pa.

UNIVERSITY OF ILLINOIS

BUTTERS, H. M. (Student, 1910), 210 E. Green St., Champaign, Ill.
BUYERS, D. E. (Student, 1910), 502 E. Green St., Champaign, Ill.

UNIVERSITY OF WISCONSIN

CHRISTIE, H. A. (Student, 1910), 229 W. Gilman St., Madison, Wis.
GRAY, C. F. (Student, 1910), 811 W. Johnson St., Madison, Wis.
SUHS, G. H. (Student, 1910), 225 W. Gilman St., Madison, Wis.
THOMPSON, O. T. (Student, 1910), 225 W. Gilman St., Madison, Wis.

COMING MEETINGS

April–May

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AIR BRAKE ASSOCIATION

May 10–13, Dennisson Hotel, Indianapolis, Ind. Subjects for discussion, and chairmen: Air Brake Instruction, Examination and Rating, Thos. Clegg; Air Pump Piping, Fittings and Connections, George W. Kiehm; Best Arrangement of Air Pump and Main Reservoir Capacity for100-car Train Service, P. J. Langan; Brake Cylinders and Connections to Cylinder Leakage, W. P. Garabrant; Inspection and Cleaning of Triple Valves and Brake Cylinders, C. P. McGinnis; Developments in Air Brakes, W. V. Turner; New York Brake Equipment, T. F. Lyons; Westinghouse Equipment, S. G. Down; Recommended Practice, S. G. Down. Secy., F. M. Nellis, 53 State St., Boston, Mass.

AMERICAN ASSOCIATION ELECTRIC MOTOR MANUFACTURERS

May 18, Newport News, Va. Secy., Frank H. Couch, Hampton.

AMERICAN ASSOCIATION OF LOCAL FREIGHT AGENTS

April 19–22, Mobile, Ala. Secy., G. W. Dennison, Toledo, O.

AMERICAN ELECTROCHEMICAL SOCIETY

May 5–7, Spring Meeting, Pittsburg, Pa. Addresses on the Present Status of Electrochemical Industries; Pittsburg as an Electrochemical Center; the Conservation of Natural Sources of Power. Secy., Dr. J. W. Richards, Lehigh University, South Bethlehem.

AMERICAN EXPOSITION IN BERLIN

June 1–Aug. 31, American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN FOUNDRYMEN'S ASSOCIATION and AMERICAN BRASS-FOUNDERS' ASSOCIATION

May 18–20, joint convention, Cincinnati, O. Secy., A. F. A., Richard Moldenke; A. B. F. A., W. M. Corse.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

March 30–April 1, Charlotte, N. C. Papers: Electric Drive in Textile Mills, A. Milmow; Gas Engines in City Railway and Light Service, E. D. Latta, Jr.; Modifications of Hering's Laws of Furnace Electrodes, A. E. Kennelly; The Proportioning of Electrodes for Furnace Electrodes, Carl Hering; Some Demonstrations of Lightning Phenomena, E. E. F. Creighton; Economics of Hydroelectric Plants, W. S. Lee; A Method of Protecting Insulators on the Lines of the Niagara and Lockport Power Company, L.

C. Nicholson. April 21, San Francisco, Cal. Papers: Economics of a Generator Power System, P. M. Downing; Hydroelectric Developments and Irrigation, J. C. Hays. July 31, annual meeting., 29 W. 39th St., New York. Secy., R. W. Pope, 29 W. 39th St.

AMERICAN MATHEMATICAL SOCIETY

April 30, Columbia University, 150 W. 116th St., New York Secy., F. N. Cole.

AMERICAN PORTLAND CEMENT MANUFACTURERS

April 12. Secy., Percy H. Wilson, Philadelphia, Pa.

AMERICAN RAILWAY ASSOCIATION

May 18, New York. Secy., W. F. Allen, 24 Park Pl.

AMERICAN RAILWAY INDUSTRIAL ASSOCIATION

May 10, Memphis, Tenn. Secy., Guy L. Stewart, S. W. Ry., St. Louis, Mo.

AMERICAN SOCIETY OF CIVIL ENGINEERS

April 6, 20, 220 W. 57th St., New York. Papers, April 6: New York Tunnel Extension of the Pa. R. R.; The Terminal Station, West, B. F. Cresson, Jr.; The Bergen Hill Tunnels, F. Lavis. Papers, April 20: Federal Investigation of Mine Accidents, Structural Materials and Fuels at Pittsburg Testing Station, H. M. Wilson.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

April 9, St. Louis, Mo., with St. Louis Section, A. I. E. E., and Engineers Club of St. Louis. April 12, 29 West 39th. St., New York. April 27, Auditorium Edison Electric Illuminating Co. of Boston, Boston, Mass., Boston Section, A. I. E. E., and Boston Soc. C. E., coöperating. May 31–June 3, Spring Meeting, Atlantic City, N. J. July 26–29, meeting in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SUPPLY AND MCHY. MFRS. ASSOC. and SOUTHERN SUPPLY AND MCHY. DEALERS ASSO.

April 5–7, Convention, Seminole Hotel, Jacksonville, Fla.

AMERICAN WATER WORKS ASSOCIATION

April 26–30, annual convention, New Orleans, La. Paper: New Orleans Sewerage and Water Supply Systems, G. C. Earl. Secy., J. M. Diven, 14 George St., Charleston, S. C.

BROOKLYN POLYTECHNIC STUDENT SECTION, AM. SOC. M. E.

April 9. Paper: Engineering and Common Sense, William Kent, Mem. Am.-Soc.M.E. Secy., Percy Gianella.

CANADIAN FREIGHT ASSOCIATION

April 14, annual meeting, Montreal. Secy., T. Marshall, Toronto, Ont.

FLORIDA ELECTRIC LIGHT AND POWER ASSOCIATION

April 12, annual meeting, Tampa. Secy., G. I. Doig, Gainesville.

INTERNATIONAL MASTER BOILERMAKERS' ASSOCIATION

May 24–27, New Clifton Hotel, Niagara Falls, Ont. Secy., Harry D. Vought, 95 Liberty St., New York.

INTERNATIONAL RAILWAY FUEL ASSOCIATION

May 23–26, Chicago. Secy., D. B. Sebastian, 327 LaSalle St.

IOWA ELECTRICAL ASSOCIATION SHOW

April 20–21, Sioux City. Secy., W. N. Keiser, Des Moines Electrical Co., Des Moines.

IOWA STREET AND INTERURBAN ASSOCIATION
April 20, 21, Sioux City. Secy., L. D. Mathes, Dubuque.

MISSOURI ELECTRIC AND GAS ASSOCIATION
April 14–16, Jefferson City. Secy., C. L. Clary, Sikeston.

MODERN SCIENCE CLUB
April 12. Annual election, 125 S. Elliott Pl., Brooklyn, N. Y. Secy., J. A. Donnelly.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS
April 27, 28, annual meeting, Boston. Secy., Dr. C. J. H. Woodbury, Mem.Am.Soc.M.E., Box 3772.

NATIONAL ASSOCIATION OF MANUFACTURERS
May 16–18, New York. Secy., George S. Boudinot, 170 Broadway.

NATIONAL DISTRICT HEATING ASSOCIATION
May, annual meeting, Toledo, Ohio. Secy., A. C. Rogers.

NATIONAL ELECTRIC LIGHT ASSOCIATION
May 23–28, St. Louis, Mo. Secy., Frank H. Tate, Dayton, O.

NATIONAL GAS ASSOCIATION OF AMERICA
May 17–19, Oklahoma City, Okla. Secy., M. W. Walsh, 110 N. Broadway.

NATIONAL MACHINE TOOL-BUILDERS ASSOCIATION
May 24, 25, Spring Convention, Hotel Seneca, Rochester, N. Y. Secy., C. E. Hildreth, Worcester, Mass.

NATIONAL METAL TRADES ASSOCIATION
April 13, 14, annual convention. Hotel Astor, New York.

NEW ENGLAND WATERWORKS ASSOCIATION
April 13, special meeting, Hartford, Conn. June, Providence, R. I. September 14–16, annual convention, Rochester, N. Y. Secy., Willard Kent, Narragansett Pier, R. I.

OHIO SOCIETY OF ENGINEERS
May 19, 20, Cincinnati. Secy., F. E. Sanborn, Ohio State University, Columbus.

PENNSYLVANIA STATE GAS ASSOCIATION
April, Easton. Secy., W. H. Merritt, Lebanon.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
April 26, West Hall, R. I. School of Design, 8 p.m. Paper: Oxy-Acetylene Welding and Cutting, Henry Cave; May 24, Modern Machine Tools. Secy., Prof. T. M. Phetteplace, Mem.Am.Soc.M.E., 48 Snow St.

SOCIETY OF CHEMICAL INDUSTRY
April 1, annual meeting, New England Section. Secy., Alan Claflin, 88 Broad St., Boston, Mass.

STEVENS ENGINEERING SOCIETY
April 5, 12, 19, 26, Hoboken, N. J. Papers: Theory of Gyroscopic Motion, L. A. Martin, Jr.; Handling Concrete Work, F. B. Gilbreth, Mem.Am.Soc.-M. E.; Notable Examples in Modern Construction, J. C. Ostrup; Development of the New Navy, D. W. Taylor.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
April			
2	Amer. Soc. Hungarian Engineers and Architects	Z. deNemeth	8.30
7	Blue Room Engineering Society	W. D. Sprague	8.00
12	The American Society of Mechanical Engineers	C. W. Rice	8.15
12	Amer. Soc. Engineering Contractors	D. J. Hauer	2.30 8.00
14	Illuminating Engineering Society	P. S. Millar	8.00
15	New York Railroad Club	H. D. Vought	8.15
15	American Institute of Electrical Engineers	R. W. Pope	8.00
19	New York Telephone Society	T. H. Lawrence	8.00
27	Municipal Engineers of City of New York	C. D. Pollock	8.15
29	American Institute of Electrical Engineers	R. W. Pope	8.00

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Geo. M. Bond .... Hartford, Conn.
R. C. Carpenter .... Ithaca, N. Y.
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Terms expire at Annual Meeting of 1910

Charles Whiting Baker .... New York
W. F. M. Goss .... Urbana, Ill.
E. D. Meier .... New York

Terms expire at Annual Meeting of 1911

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Members of the Council for 1910

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Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

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I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

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SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
F. R. Hutton
G. M. Basford
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
L. D. Burlingame
Charles Whiting Baker
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
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William J. Baldwin
Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
E. R. Fellows
Hugo Bilgram
C. R. Gabriel
Gaetano Lanza

On Power Tests

D. S. Jacobus, *Chairman*
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Edward F. Miller
Edward T. Adams
William Kent
Arthur West
George H. Barrus
Charles E. Lucke
Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Meetings of the Society in Boston

Ira N. Hollis, *Chairman*
I. E. Moultrop, *Secretary*
Edward F. Miller
J. H. Libbey
Charles T. Main

On Meetings of the Society in St. Louis

Wm. H. Bryan, *Chairman*
Ernest L. Ohle, *Secretary*
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Note—Numbers in parentheses indicate number of years the member is yet to serve.

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

AMBROSE SWASEY (1)
CHAS. WALLACE HUNT (3)
F. R. HUTTON (2)
HENRY R. TOWNE (4)

On Board of Trustees United Engineering Societies Building

F. R. HUTTON (1)
FRED J. MILLER (2)
JESSE M. SMITH (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE, AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

GEO. H. BARRUS
P. W. GATES
W. F. M. GOSS

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909

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J. R. Bibbins

SECRETARY

Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

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F. R. Hutton (3)
G. I. Rockwood (2)
H. H. Suplee (4)
F. R. Low (5)

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C. T. Wilkinson

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G. D. Conlee
T. M. Phetteplace
R. S. de Mitkiewicz
G. J. Rathbun
L. V. Goebbels
S. A. Reeve
L. N. Ludy
A. L. Rice
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L. B. Lent, *Chairman*
A. Bement
C. B. Rearick

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
C. N. Duffy
J. D. Andrew
H. J. K. Freyn
C. J. Davidson
W. S. Twining
C. W. Whiting

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
E. T. Adams
Arthur West
James D. Andrew
J. R. Bibbins
H. F. Smith
Louis C. Doelling

Note—Numbers in parentheses indicate number of years the member is yet to serve.

OFFICERS OF STUDENT BRANCHES

STUDENT BRANCH	AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	....	C. F. Hirshfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford, Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	E. A. Rogers	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	E. W. Templin	H. A. Houston
Univ. of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morril Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	W. H. Montgomery	P. G. Haines
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	R. N. Trane	G. A. Glick
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. E. Dudley	F. T. Kennedy
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	M. E. Strieter	A. D. Stancliff
	1910			
Univ. of Maine, Orono, Me.	February 8	....	....	....